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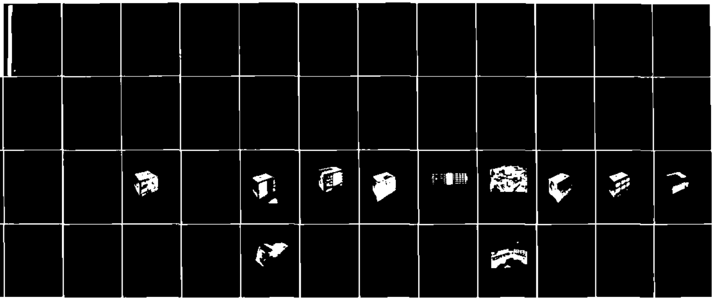

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AERODYNAMICS REPORT 155

A VERSATILE DATA ACQUISITION SYSTEM FOR A LOW SPEED WIND TUNNEL

by

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SUMMARY

A data acquisition system for the Aeronautical Research Laboratories Low Speed Wind Tunnel is described. The system is versatile and simple to operate. Illuminated press button switches connect selected data sources with the addresses automatically generated within the system. Provision also exists for external addressing by a dedicated minicomputer.

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16. **ABSTRACT**

A data acquisition system for the Aeronautical Research Laboratories Low Speed Wind Tunnel is described. The system is versatile and simple to operate. Illuminated press button switches connect selected data sources with the addresses automatically generated within the system. Provision also exists for external addressing by a dedicated mini-computer.

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A

1. INTRODUCTION

A Data Acquisition System (DAS) developed at the Aeronautical Research Laboratories for the Low Speed Wind Tunnel is described. Design began in 1972 and installation commenced in 1975 with selected modules being used during 1974.

The system is easily programmed by manual press button switches to select from a wide range of data sources. The selected sources are automatically addressed in a prearranged sequence, usually by internal addressing circuits but external addressing under software control from a dedicated minicomputer may also be used. At present the data recording rate is determined by the speed of the output storage device. This device may be a standard Teletypewriter with a paper tape punch attachment, a magnetic recorder or a disc unit when data are dumped on-line to a DECsystem-10 central computer.

The DAS was specifically developed to acquire:

(1) Force and moment data from a six component strain gauged sting column rig.
(2) Force and moment data from a six component mechanical balance.
(3) Pressure data from six Scanivalves.
(4) Hinge moment data from strain gauged linkages which actuate model control surfaces such as rudder and flaps.
(5) Angular data of model control surfaces.
(6) Angular data of model axes with respect to conventional reference axes.
(7) Manually inserted tunnel and model constants.
(8) Supplementary data such as time, day, tunnel air temperature, atmospheric pressure and humidity.
(9) Miscellaneous data from as many as sixteen sources used in special wind tunnel investigations.

Data Selection Switches, mounted on the front panel of the Data Sequence Selector Module (DSSM), enable the operator to select the sources from which data are required. Also an automatically generated and recorded code block provides the operator and data processing computer with the means of positively identifying all recorded data.

Quick look facilities exist for specific data to be displayed graphically on a microprocessor controlled storage display unit or X–Y digital plotter.

Input data to the DAS are accepted in both analogue and digital Binary Coded Decimal (BCD) 1248 form, while the output is available in both parallel and serial American Standard Code for Information Interchange (ASCII) with analogue outputs provided from some sources.

The data specifications of individual data source modules of the DAS are given in Appendix 1.

2. DESCRIPTIONS OF THE DATA ACQUISITION SYSTEM

2.1 General

A block diagram of the complete DAS is shown in Figure 1. Analogue input signals from selected sources are digitized by digital panel meters which provide both the required analogue to digital conversions and the numerical displays for the equipment operator. Digital input signals obtained directly from some selected sources and those obtained from the digital panel meters are applied to integrated circuit serializers. The serializer addresses are generated directly by circuits within the DSSM unless externally controlled by a dedicated minicomputer.

The addressing speed is usually determined by the speed of the data storage device but one data source which imposes a restriction on the addressing speed is the Scanivalves (Section 2.8). Scanning speed of the pressure ports is determined by the selected settling time; i.e. the minimum time that the Scanivalve is to be stationary at a given pressure port to obtain a steady output reading for a step change in input pressure. Also, Scanivalves are inherently slow because

of the electromechanical pressure port selector. Except for the Scanivalves, all other data sources have a constant or purposely frozen reading during the time that the serializers are sequentially addressed to acquire the static aerodynamic data.

Initially, an existing Teletypewriter with paper tape punch attachment was used as the output data storage device to provide a typewritten copy of the data for verification of the punched paper tape record. This tape, punched in ASCII code, was later read into the DECsystem-10 central computer. Policy at the time did not permit data acquisition systems to be connected on-line to the time sharing central computer.

Relaxation of the policy now allows data to be stored directly on disc within the DECsystem-10 time sharing computer. To verify proper data handling all characters received from the DAS are automatically read from disc, immediately after storage, and echoed to the DAS Teletypewriter.

An automatic switch within the DAS allows the Teletypewriter to function as a normal terminal to the DECsystem-10 when no data is being acquired (DAS READ switch not pressed).

The internal addressing circuits respond to decoded X-ON and X-OFF calls under the time sharing mode of operation to avoid loss of data through buffer overflow.

2.2 Data Sequence Selector Module (DSSM)

This module (Fig. 2) forms the heart of the DAS. All data sources are connected through this module to the output device. The DSSM is programmed by the operator, prior to the first tunnel run, to select the required data sources. The Data Selection Switches are of the illuminating push-button type which light only when in the selected state, provided that the selected data source is correctly connected and powered.

Selectable data sources are:

Fixed Data	(one selection switch)
Preset Data	(sixteen selection switches)
Mechanical Balance	(six selection switches)
Auxiliary 1	(eight selection switches)
Auxiliary 2	(eight selection switches)
Strain Gauge 1	(six selection switches)
Strain Gauge 2	(six selection switches)
Scanivalves	(one selection switch)

Reading of data through the DSSM is initiated by a preselected push-button switch (READ). For convenience READ switches are provided on the front panel of each of the major data source modules. Once the READ command has been received by the DSSM, the DSSM initiates either an interrogation scan followed by a data scan or simply a data scan.

The interrogation scan senses and records the states of all the Data Selection Switches as part of a code, and occurs only if the fixed data source is selected (Figs 3A and 3B).

With fixed data selected, the DSSM addresses and outputs information in the following order on receipt of a READ command.

1. Time and day, relative humidity and temperature, atmospheric pressure and kinetic tunnel pressure.
2. A pattern of three automatically generated code blocks.
3. Data gathered from the selected data sources.

The first line of the fixed data block of a typical record (Fig. 3A) shows information corresponding to 1 above. The second line contains the first code block and relates to the state of all the Data Selection Switches on the DSSM. A recorded "1" denotes the selection of a data source and a "0" denotes the non-selection of a data source. The third line contains the second and third code blocks. The second block relates to the two strain gauge sources whereby a number between "1" and "8" denotes the sensitivity setting of each selected strain gauge amplifier and a "0" denotes non-selection of an amplifier. The third block relates to the Scanivalves and consists of six groups. Each group contains a letter (A through to F) followed by two digits. The letter identifies the Scanivalve and the digits represent the number of pressure ports selected on each of the Scanivalves.

Whenever the DSSM outputs data directly to a Teletypewriter, the code enables easy identification of the blocks of recorded data. When a data source is selected but not powered or correctly connected to the DSSM, a diagnostic symbol is usually forced automatically to replace the appropriate alphanumeric character of the code (Fig. 4).

During the data scan, internal DSSM address circuits sense the state of the Data Selection Switches to provide addresses only to those sources selected. Fast address skips are automatically generated when non-selected sources are detected (Section 3.12).

Should a HOLD flag occur, further addressing is inhibited until the flag drops. Data are not lost nor is there a discontinuity in the record because of a HOLD and its subsequent removal. Invalid data produced by signal overload of strain gauge or Scanivalve data sources are automatically recorded as question marks.

When using internal addressing, the DSSM decodes every address word as it is generated. These hard wired decoder circuits (Section 3.8) control the logic states of bits (b5 through to b8), which, when combined with the gathered four bit BCD data word, form a parallel eight bit word corresponding to the required ASCII character.

The decoder circuits also cause spaces, line feeds and carriage returns to be inserted in the record at the appropriate places (Section 3.7).

The Teletypewriter is a two line serial device, which requires serialized bits to be synchronized with mechanical motion within the Teletypewriter (Section 3.4). Conversion from parallel to serial form is accomplished with a shift register clocked at the required rate by a frequency stabilized oscillator within the DSSM. A start and two stop bits are added to the serialized eight bit ASCII coded data.

2.3 Fixed Data Module

This module (Fig. 5) provides visual and digital data which relates to conditions prevailing at the time that the test data are recorded.

A twenty-four hour digital clock, locked to the mains frequency, provides both the time (in increments of one minute) and the day of the year sequentially numbered from 1st January.

Provision has been made to include data from instruments measuring relative humidity, temperature and atmospheric pressure.

Kinetic pressure data are obtained from a transducer (shaft encoder) coupled to a Velodyne unit that measures the pressure difference between two pressure sampling pitot rings in the wind tunnel. The electrical output from the transducers is in Pethrick code and is converted to BCD 1248 code by combinational logic circuits for gathering by the DSSM.

2.4 Preset Data Sources

Preset data refers to data gathered from three sources by three separate modules. The first source is derived from nine banks of thumbwheel switches located on the front panel of the DSSM. These switches enable model code, configuration and preset constants to be manually dialled for entry as data.

The second source is derived from the Model Attitudes Module (Fig. 6), whereby angular data are provided from shaft encoders connected to the wind tunnel turntables, the roll and yaw mechanism of the sting column and the pitching arm of the mechanical balance. These angular data relate to the attitude of the model with respect to the wind axis reference.

The third source is derived from the Model Control Deflections Module (Fig. 7) whereby angular data are obtained from three separate but identical digital servo systems driving model actuators. These actuators fit into aerodynamic models and are mechanically coupled to the control surfaces such as flaps and rudder. The analogue output from an actuator is converted to digital form by a digital panel meter. This meter is scaled to give a direct reading in degrees of the control surface angle with respect to the model datum line.

The operator simply dials the desired angle and the appropriate control surface is remotely positioned by the servo system. Limit switches prevent the servo systems from driving beyond predetermined angles. Strain gauges, attached to each actuator, also enable the hinge moments acting on the control surfaces to be measured (Section 2.7).

2.5 Mechanical Balance

This module (Fig. 8) provides six channels of numerical display and digital data and also houses the instrumentation for six self-balancing digital servo systems. Forces and moments acting on a model, connected to the mechanical balance, are coupled through mechanical linkages to six weighbeams. These weighbeams (Fig. 9) are independently controlled by digital servo systems which sense for out of balance of the beam and drive a stepper motor to reposition a travelling mass to rebalance the beam.

The distance the travelling mass moves is representative of the moment or force acting on the model. This mass is coupled through a precision lead screw and gear box to the stepper motor, hence the arithmetical sum of the number of steps taken by the stepper motor to rebalance the beam is proportional to the applied moment or force.

Up-down digital counters arithmetically total the number of electrical control pulses applied to each stepper motor. Suitable scaling enables direct reading numerical displays (in Newtons or Newton metres) with corresponding BCD 1248 outputs for recording by the DSSM.

2.6 Auxiliary

Two identical modules (Fig. 10) have been provided, each capable of accepting eight input channels of up to eight characters. These Auxiliary Modules allow data to be gathered by the DSSM from sources additional to those specifically allocated.

The word length of each auxiliary channel is independently set on thumbwheel switches mounted behind the front panel of the Auxiliary Modules.

To illustrate the versatility of these modules, consider the powered Model Control Module (Section 12) which contains two tachometers to measure the rotational speed of the model propellers. The tachometer readings may be recorded as auxiliary data by simple connections and adjustment of the appropriate channel word length switch.

2.7 Strain Gauge Control

Two identical Strain Gauge Control Modules (Fig. 11) each connect to six San-El strain gauge amplifiers mounted in modules (Fig. 12). A common frequency carrier (nominally 5 kHz) excites the strain gauge bridges and each amplifier produces an analogue output proportional to the strain applied to the strain gauge bridge. These analogue outputs connected to digital panel meters provide the required BCD 1248 outputs and visual displays for the operator. Switched filters, with cut-off frequencies at 0·6 and 6 Hz, smooth the analogue signals when model buffeting or vibration occur. With the filters switched out the pass band of the strain gauge amplifiers approaches 3 kHz.

One Strain Gauge Control Module is normally connected to the sting column balance to measure forces and moments applied to a model mounted on this balance. The other module is available to measure hinge moments from strain gauges attached to actuators (Section 2.4), or for other *ad hoc* measurements that require the use of strain gauge bridges.

A calibration switch is provided on each Strain Gauge Control Module to inject a signal into the strain gauge amplifiers for calibration purposes.

Whenever a strain gauge amplifier overloads, a self-cancelling flashing light operates to attract the operator's attention. As mentioned in Section 2.2 overload data are not recorded but are automatically converted to question marks.

2.8 Scanivalve Control

Pressure measurements for determining pressure profiles of aerodynamic models are carried out using Scanivalves. The Scanivalve Control Module (Fig. 13) is capable of controlling six Scanivalves each able to select and measure sequentially forty eight pressure ports. As each port is selected the line pressure at that port impinges upon a strain gauged diaphragm forming a pressure transducer.

Each Scanivalve strain gauge bridge connects to a strain gauge amplifier and the analogue outputs are multiplexed to a single digital panel meter to provide the required BCD 1248 output and numerical display.

The operator predetermines the number of pressure ports to be recorded from each Scanivalve by dialling the appropriate port information on a bank of thumbwheel switches. A common settling time is adjustable in increments of 0·1 seconds from near zero to 99·9 seconds by another switch ensuring that a time delay of sufficient duration occurs to allow measurement of the steady state pressure following every port selection. Hence, to obtain the desired reading rate the DSSM is subjected to hold flags or interrupts when addressing pressure data from the Scanivalve Control Module.

3. DATA SEQUENCE SELECTOR MODULE

3.1 General

Within the DAS, all addressing of the digital data sources is carried out by hardwired circuits. To avoid generating unwanted addresses the state of the Data Selection Switches located on the front panel of the DSSM (Fig. 2) is sensed to provide the appropriate skip flags. Decoder circuits continuously sense the state of the address lines to force the appropriate Teletypewriter commands (space, carriage return and line feed). This separates the typewritten record into easily recognisable data blocks.

Where a dedicated computer is used the internal addressing and decoding circuits of the DAS are inhibited, as all addressing and forming of data blocks is under software control. Section 13 describes a general purpose program used to control the DSSM for evaluation studies.

3.2 Clock Generation

Though the extensive use of Transistor-Transistor Logic (TTL) integrated circuits, the address and cycle time is only a few microseconds and is well suited to on-line computer operation. Initially, to enable the DSSM to output directly into a Teletypewriter, the clock generation circuits were designed specifically for serial output of eight bit ASCII at nominally ten characters per second. Parallel eight bit ASCII is also available for recording of data by an incremental tape recorder, thus allowing the internal clock rate to be significantly increased.

A square wave oscillator provides the basic clock and for 110 baud operation the clock frequency must remain within 2% of 880 Hz to avoid a loss of coincidence between the transmitted data bits and the Teletypewriter distributor. Timing errors produced by frequency drift cause incorrect characters to be recorded.

3.3 Timing Lines

Timing of events throughout the DSSM is controlled by cyclic pulse lines (Fig. 14) with pulses on each line being time shifted with respect to pulses on other lines. All pulses are derived from logic gates and frequency divider networks driven from the master oscillator.

Five cyclic pulse lines ($\phi 1$ to $\phi 5$) are provided to gate events such as the resetting of latches and the clocking of counters. For correct operation, these events are performed in a time controlled sequence. Other cyclic pulse lines load and clock data bits through the shift register to the Teletypewriter.

3.4 Cycle Time

The DAS now connects to a Teletypewriter Model 43 which operates at 300 baud. This speed increase simply required the oscillator frequency to be increased from 880 Hz to 2·4 kHz, however, the following cycle time description refers specifically to early operation at 110 baud with an ASR 33 Teletypewriter.

A complete address and read cycle occurs in 96 cycles of the master oscillator, or nominally every 109 milliseconds.

Teletypewriter operation requires the serializing of eleven equal time segments, each segment being 9·08 milliseconds duration (Fig. 15). The sequential order of the segment functions are one start segment followed by eight character segments (each represents a single bit of the ASCII coded character) and two stop segments. Each segment produces a state such that current either flows or is cut-off to a fast acting electromechanical latch, located within the Teletypewriter.

Timed operation of the latch enables revolving cams to be positioned such that mechanical feeler arms are able to accurately control the rotational and vertical indexing of the type head. The time required to output one ASCII character is 99·88 milliseconds. One additional time segment has been provided, between the end of the stop and the beginning of the start, giving the total cycle time of 108·96 milliseconds.

3.5 Data Address

A data address consists of an eleven bit word and for convenience of description this is divided into three separate address words. The three most significant bits of the address selects the data source or system from where data are to be obtained, e.g. mechanical balance, model control settings etc. The next four bits address the channel or function of the selected system, e.g. pitch, roll etc. The four least significant bits, address the individual characters or decades of the selected function. Hence S3.F1.D6 refers to system 3 (mechanical balance) function 1 (Lift) decade 6 (6th character).

The corresponding binary address word is 011 0001 0110. However, conventional "octal" addresses are normally used to make the DSSM compatible with standard computer notation. The above 11 bit data address word corresponds to the octal word 1426.

3.6 Generation of Data Addresses

System, function and decade addresses are derived from the A, B, C and D bits of three independently clocked and resetable four bit binary counters. The D bit of the system counter remains continuously low as only eight system addresses are used. However, all sixteen states of the function and decade addresses are used requiring all (A, B, C and D) bits of these counters.

Clocking and resetting of the three counters are derived from combinational logic given by the following Boolean equations.

Decade Clock =	Ø3 . Not All character commands
Function Clock =	Carriage return line feed command . double spaced command . space command
System clock =	Carriage return double line feed command + end of Scanivalves command
Decade reset =	Carriage return double line feed + carriage return single line feed command + double space command + single space command
Function reset =	Carriage return double line feed command + S8.F8.D7
System reset =	Not Read command

Where: . is logical "AND"

+ is logical "OR"

"All character commands" is the "OR" of the following individual commands:

Carriage return double line feed + carriage return single line feed + double space + single space + space restricted

Ø3 is the phase three clock line (Section 3.3).

S8.F8.D7 is the seventh decade character of the eighth function to be recorded in system eight, which corresponds to the completion of a typewritten line of data from the Scanivalve data block.

3.7 Data Blocking

Spaces and carriage returns with line feeds provide a convenient means of blocking the recorded data (Fig. 16). A carriage return double line feed is inserted at the beginning and end of a data gathering record; therefore each record is separated by four consecutive line feeds. Carriage return double line feeds are also inserted within the record at the end of each system block of data.

Where data within a system block exceed one line, a carriage return single line feed is inserted. Spaces are inserted at the end of each recorded data word, i.e. at the end of each recorded function.

When more than one character command is simultaneously called, a priority circuit enables a carriage return double line feed to have precedence over all other commands. The carriage return single line feed then has precedence over a space.

Apart from providing a neatly typed record for the operator such blocking, in conjunction with the automatically generated code, enables computer identification of specific data during processing of the raw data.

3.8 Decoding Data Addresses

All the necessary information for determining when commands should occur exists in the data addresses. For example, the data address S3.F2.D8. is the last character of drag data from the mechanical balance. Immediately this character is recorded a space is called and the function counter clocked to F3 and the decade counter reset to D1, to change the data address to S3.F3.D1.

The command character is thus decoded from the data address ahead of the position whereby the command character is required. The command character call is inhibited until the data at that particular address have been recorded. The data address lines are then inhibited until the command character or characters have been recorded.

Decoding of the data address is initiated by BCD to decimal decoders connected to each of the system, function and decade addresses lines (Fig. 17). The system address uses only eight states and a single ten channel decoder suffices, but both the function and decade addresses use all sixteen states and two decoders are interconnected to accommodate these sixteen input states.

The output logic levels of each decoder are all high except for the one output which corresponds to the applied input code. By standard convention all the decoder outputs are negated (N) i.e. N Sx.N Fy.N Dz. The active range of x is from 1 to 9, y is from 1 to 16 and z is from 1 to 16. For general description the negations are omitted.

Various command flags are obtained from combinational logic circuits connected to the decoder outputs. For example, the carriage return single line feed command flag is obtained from:

$$S1\,(F4.D6 + F8.D8) + S2.F9.D7 + S8.F8.D7$$

There are seven command flags in all and these are:

1. Carriage return double line feed.
2. Carriage return single line feed.
3. Double space.
4. Single space.
5. Single space restricted.
6. Sign.
7. Letter.

The single space restricted command differs from the single space command in that when the restricted space is called there is no decade reset or function clock pulse generated. The sign and letter commands are required by the bit controller (Section 3.10) to set the logic states of bits 5, 6 and 7 in the eight bit ASCII output. The eighth bit is automatically determined by a parity generator circuit.

3.9 Serializers

The data address (Section 3.5) controls single pole digital switches of either eight or sixteen positions. The logic states of the data address determines the pole position of the switch. These switches are grouped in sets of four to provide banks of four pole digital switches known as serializers. Four poles are required to switch simultaneously each of the BCD coded A, B, C and D data word bits. Thus digital data connected to the input of these switches are selectable by the data address.

A three level grouping of serializers is employed (Fig. 18). The lower level is controlled by the system address, the middle level by the function address and the upper level by the decade address.

The four data lines (A, B, C and D) from the output serializer become the four least significant bits (b0, b1, b2 and b3 respectively) of the eight bit ASCII output. The remaining four ASCII output bits (b4, b5, b6 and b7) are inserted automatically by the bit controller circuit.

As the serialisers are four pole devices, the number of unique logic states that can be directly sensed as data is limited to sixteen but this can be exceeded provided additional information contained in the data address is used. The numerals 0 through to 9 are allocated conventional BCD weighting and three other states are allocated to a decimal point and the signs plus and minus.

3.10 Bit Controller

Commands, decoded from the data address (Section 3.8), form the inputs to the bit controller combinational logic circuits. These inputs, with the exception of sign and letter, are time delayed by latches in the command counter circuit (Section 3.11).

Whenever a sign or letter command is decoded from the address, the command acts immediately as the data selected by the serializers represents either a sign or letter. These selected data appear at the output of the DSSM as b0, b1, b2 and b3 and the command engages the bit controller logic to set b4, b5, and b6 to the appropriate states for either a sign or letter. Parity bit (b7) is determined by a parity generator, for either odd or even parity as desired based on the states of the other seven output bits. The resulting eight bit parallel ASCII word is loaded into an eight bit shift register and clocked with the necessary start and stop information to the Teletypewriter.

Whenever commands, other than sign and letter, are decoded from the data address, these commands are delayed as the data selected by the serializers must appear at the output of the DSSM before the command takes effect. Immediately the data character is recorded, the delayed command sets the states of the seven output bits of the bit controller to record the first command character, the eighth bit being automatically set by the parity generator.

Since the command may require more than one operation (e.g. carriage return double line feed), a command counter is activated by the commands to control the number of operations.

3.11 Command Counter

The command counter registers the number of consecutive character operations performed when a command other than a sign or letter is called. Moreover, in conjunction with specific commands, the counter changes the states of the bits loaded into the shift register. For example, when carriage return double line feed is called by the command decoder, the command counter registers and delays this command until the sensed data digit is recorded. The command counter then clocks to the carriage return position and after one operation advances to the line feed position where it remains for two more operations before being reset.

When the counter is in the carriage return position the bit controller sets the output bits to the ASCII code for carriage return. The command counter in advancing to the line feed positions causes the bit controller to change the state of the output bits to correspond to the ASCII code for line feed.

The command counter, when reset at the completion of a command sequence, provides the appropriate reset and clock controls to the system, function and decade counters. Data are again read through the serializers until another command is decoded.

3.12 Address Skipping

The Data Selection Switches on the front panel of the DSSM are addressed sequentially. The state of these switches is either a logical "1" if in the selected position or a logical "0" if not selected. If all switches of a system data block are "not selected", then a system skip occurs causing the system counter to clock rapidly to the next position. Skipping continues until a block is reached that has at least one selected Data Selection Switch.

When a system block is reached in which one or more functions are selected the state of the Data Selection Switches in the block are sensed sequentially and whenever a "not selected" state is detected the function counter is rapidly clocked forward until a "selected" function is sensed. The decade counter then addressess this function to record the data characters.

Whenever system and function skips occur, the recorded data are automatically packed to the left side of the typewritten record. This avoids typing zeros or spaces in the place of the unselected data and minimises the data acquisition time.

The states the Data Selection Switches are recorded in the fixed data block as a code to enable positive identification of all recorded data. Under computer control the state of the switches would be sensed to enable the software to manipulate the address table and only gather data from selected functions.

3.13 Read Selection

The DSSM has, in addition to a READ switch, a Read Selection Switch which allows a choice of READ switch operation from one of several modules.

With the Read Selection Switch in the extreme anticlockwise position (MECH BAL) only the READ switch on the mechanical balance module is able to initiate a READ to record all the selected data. Likewise, control is transferred to the auxiliary, strain gauge or Scanivalve modules as the Read Selection Switch is progressively rotated clockwise. In the extreme clockwise position, control is transferred to the READ switch on the DSSM. However, in this position, a READ is only initiated after the READ switches on all selected modules have been pressed.

As each READ switch is pressed, data associated with that source is immediately frozen and a light emitting diode illuminates alongside the appropriately labelled position of the Read Selection Switch. Modules that are not selected, or not switched on, automatically cause their appropriate indicator to light. It is only when all indicators are lit that the operator, positioned at the DSSM, is able to initiate a READ action.

All READ switches have illuminated push buttons that light when the read request is received by the DSSM and are extinguished when all the selected data have been recorded, or a manual reset is applied.

4. FIXED DATA MODULE

4.1 Digital Clock and Day Counter

The digital clock and day counter is powered from a separate mains supply to ensure that it is not normally switched off. Timing pulses are generated from the 50 Hz mains supply, to trigger the divider logic circuits that produce the required display of days, hours and minutes. Controls, situated behind a hinged door in the front panel of the module (Fig. 5), enable the clock to be initially set to the correct time.

4.2 Kinetic Pressure

The self balancing manometer (Velodyne unit) measures the pressure difference between two pitot rings within the Low Speed Wind Tunnel. The high pressure pitot ring is situated in the settling chamber (up stream of the working section), while the low pressure pitot ring is situated in the throat of the working section.

These pitot rings are connected by tubes to two metallic bellows linked so that a pressure difference in the bellows unbalances a servo operated weighbeam. Unbalance is sensed by a displacement transducer and the electrical signal from the transducer amplified to control the rotation of a stepper motor to reposition the travelling mass and rebalance the weighbeam.

The change in position of the travelling mass is proportional to the pressure difference existing between the two pitot rings. This pressure difference is proportional to 0·5*(RHO)*(VELOCITY) squared; where RHO is the specific density of the tunnel air and VELOCITY is the tunnel air velocity.

A Pethrick coded digitizer geared to the weighbeam stepper motor provides digital information that corresponds to the direct reading of the kinetic pressure in pascals. A combinational logic decoder circuit converts the digitized Pethrick code into BCD code for acquisition by the DSSM.

5. MODEL ATTITUDES MODULE

5.1 General

Usually models are mounted in the Low Speed Wind Tunnel by one of the following methods:

(a) On pylons attached to either the top or bottom turntable of a working section.

(b) Strung between wires attached to the top and bottom turntables of a working section.

(c) Coupled to the six component Mechanical Balance.

(d) Attached to the strain gauged arm of the Sting Column Rig.

For models mounted on or between the turntables, the angle of side slip (Beta) is determined by the angular position of the turntables.

For models coupled to the six component Mechanical Balance, the angle Beta is set by the balance turntable and the angle of attack (Alpha) is set by the balance pitching arm.

For models attached to the strain gauged arm of the sting column rig, the angle of pitch (Theta) is set by the vertical angle of the arm while the angle of roll (Phi) is set by the rotation of the arm.

The operator selects the required angles (Alpha, Beta, Theta or Phi) for the recording of data, at the Model Attitudes Control Module (Fig. 6) and again by the Data Selection Switches on the DSSM. The actual angles are then displayed on the Model Attitudes Control Module and when a read is initiated the angle data are frozen and serialized by the incoming data address from the DSSM. These data are recorded in the present data block.

5.2 Shaft Encoders

Absolute shaft encoders are attached to each of the working section turntables, the six component mechanical balance turntable, the roll mechanism of the sting column rig and the control mechanism of the angle of pitch of the sting column rig.

The shaft encoders recover their readings when power to the encoder is interrupted. They operate on the phase difference between two sinusoidal signals and, in conjunction with an electronics package, provide a digital (BCD 1248) output which is direct reading in degrees of the encoder shaft angle from a reference.

6. MODEL CONTROL DEFLECTIONS MODULE

6.1 General

To simplify the setting and measuring of control surface (rudders, elevators, etc.) angles, a three channel digital servo-system was designed around existing model actuators (Fig. 19). Each servo-system contains a digital panel meter (Fig. 7) to provide both a visual display of the control surface angle and a digital output (BCD 1248 code) for recording by the DSSM.

6.2 Model Actuators

Each actuator is a small gear box controlled by a reversible 24 volt direct current motor. A miniature ten turn potentiometer provides angular feedback for automatic control of the output shaft angle. A model control surface attaches to this output shaft.

A digital comparator continually compares the angle, read by the digital panel meter, with the angle set by the operator on thumbwheel switches or with the angle set by the dedicated mini-computer (Section 13.4). The output from the comparator controls the voltage polarity applied to the actuator motor, to control the direction of rotation of the motor.

At the instant the angle read by the digital panel meter equals the set angle, power is removed from the actuator motor. Unless additional precautions are taken, inertia and backlash combine to prevent the actuator shaft rotation from stopping immediately the motor power is removed and causes the desired angle to be overshot. This again occurs when correction is applied and the servo-system hunts about the desired angle.

To reduce hunting, electrodynamic braking is applied by pulsing the motor once in the reverse direction when the comparator detects that the angles are equal. The time duration of this braking pulse is adjustable.

7. MECHANICAL BALANCE MODULE

7.1 General

Originally, each weighbeam was fitted with a differential displacement transducer that produced an error signal to the analogue servo amplifier which drove two stepper motors. One motor repositions a travelling mass, to rebalance the weighbeam, while the other motor drives a mechanical counter. The mechanics were so arranged that the counter read directly the force or moment in imperial units.

Unfortunately, these data were not in a form suitable for data acquisition. The problem was overcome by replacing the differential displacement transducer with a three bit optical displacement transducer and using a digital servo-system to drive the stepper motor to reposition the travelling mass.

During the conversion to a digital control system, the display (Fig. 8) and data output were rescaled to read directly in SI units.

The numerical display and digital output is derived from an up-down decade counter incorporated in the motor control circuit. This reversible counter clocks forward, one count whenever the stepper motor advances one step, and clocks backwards one count whenever the stepper motor moves one step in the opposite direction. The counter may be initially loaded with any desired reference value including zero. However, to control both the counter sign and counter direction logic circuits actually sense motor direction, change in direction and zero count.

7.2 Digital Displacement Transducer

Seven of the possible eight unique states of the three bit displacement transducer detect three zones of unbalance either side of the balance zone. The bit code is arranged such that only one bit changes at a time. The balance state is achieved when light is blocked to all three photo diodes.

Because of the inherently slow response of a weighbeam to changes in the restoring moment produced by incremental changes of position of the travelling mass, a time lag of many seconds occurs before a change is detectable at the displacement transducer. For this reason the stepping rate of the motor is progressively reduced as the beam approaches the balance position. The zones detected by the displacement transducer control the speed of the stepper motor. The balance zone is 0·1 mm wide and the other six zones are each 0·3 mm wide.

A microprocessor within the servo control loop to compute the converging balance value has been considered.

8. AUXILIARY MODULES

8.1 General

Each Auxiliary Module (Fig. 10) is capable of accepting up to eight data channels. Channel selection is under the control of the Data Selection Switches located on the front panel of the DSSM.

Each channel has an eight character capability, the first character being either a sign or space. To avoid gathering and recording unnecessary characters when the data word length is less than eight characters, preset thumbwheel switches are provided to select the desired word length (Fig. 10).

8.2 Word Length Adjuster

An integrated circuit four bit digital comparator compares auxiliary addresses with the bit lines from eight independent thumbwheel switches. As each channel of data is selected by the function address, the appropriate digital comparator is enabled to sense for compatibility

between a reference, provided from a switch, and the incrementing states of the decade address. Since each increment of the decade address represents an address for the next character in the data word, then by arranging for the comparator to call a space command on sensing code equality, the data word is terminated. This also causes the decade address to reset and the function address to advance to select the next required channel.

8.3 First Character in Auxiliary Data Word

In the design of the DAS it was presupposed that data, entered through an Auxiliary Module, would contain a sign as the first character (Fig. 20). However, as an alternative, a space can be recorded simply by hardwiring the four data input lines (A, B, C and D) at the first position of the data decade serializer to a logic low state. This hardwired zero data character in conjunction with the sign command, produces the octal code 240 which corresponds to a space character.

The sign or forced space counts as one character in the data word. Thus, for example, the word length switch should be set to six when recording the propeller speed (Section 12) where the data word consists of a forced space, three digits, a decimal point and one more digit.

9. STRAIN GAUGE CONTROL MODULE

9.1 General

The two identical Strain Gauge Control Modules (Fig. 11) each provide six individual numerical displays of the analogue outputs from six strain gauge amplifiers (Section 10) and six switches (Section 9.3) to enable the sensitivity of the strain gauge amplifiers to be recorded. Six mechanical indicators identify the component assigned to each strain gauge channel. Access to a six channel switchable lowpass filter is achieved by withdrawing a strain gauge control module from the console.

9.2 Data Selection Switch Illumination

The strain gauge Data Selection Switches on the front panel of the DSSM enable the operator to select the desired strain gauge channels. However, unless mains power is applied and switched ON to the appropriate Strain Gauge Control Module, the Strain Gauge Data Selection Switches will not light. Lack of such indication also occurs if incorrect connections exist between the two modules.

9.3 Strain Gauge Amplifier Sensitivity Switch

Unfortunately it was impractical to automatically monitor the gain setting of the strain gauge amplifiers, therefore a thumbwheel switch was allocated to each strain gauge amplifier to be set to a number which corresponds to the sensitivity setting of the amplifier. These switches are addressed during the code portion of the fixed data to provide a record of the sensitivity setting of each selected strain gauge amplifier.

9.4 Low Pass Filters

To improve the signal to noise ratio two lowpass filters are provided. One filter has a cut-off at 0·6 Hz to closely simulate the frequency response of a self-balancing strain gauge servo system previously used by the Low Speed Wind Tunnel. The other filter has a cut-off frequency of 6 Hz.

9.5 Analogue to Digital Conversion

Digital panel meters measure, digitize and display the analogue signals appearing at the outputs of the selected filters. The digitized BCD code is addressed through serializers in the manner described in Section 3. The digital panel meters have a range of $\pm 1{\cdot}999$ volts that provide a nominal scale length of 4000 compared with 1000 for the system used previously.

Reading rate is preset to about three readings per second for use with the 0·6 Hz low pass filter, although this is easily increased to 50 readings a second if required. The DAS was designed on the understanding that static signals prevailed. Should oscillatory signals be encountered, or

the 6 Hz filter used, then the reading rate must be increased to reduce the probability of aliasing. Aliasing is the effect of low frequency impersonation by high signal frequencies and occurs when the sampling rate is less than twice the highest frequency present.

9.6 Strain Gauge Data Freeze

All the strain gauge readings are frozen by actuating the Freeze switch. Once frozen the wind tunnel parameters may be changed without loss of reading.

Freezing also occurs automatically whenever a strain gauge read signal occurs. This is simply achieved by inhibiting the reading rate pulses generated within the digital panel meters which also avoids the possibility of the DSSM addressing a panel meter for data during an analogue to digital conversion cycle.

9.7 Calibration Record

Normally the strain gauge amplifiers are bridge balanced, zeroed and the sensitivities adjusted using an injected calibration signal with still air in the tunnel. Two READ operations are then made, one to record the zero and the other to record the reading with the calibrate signal applied.

The wind tunnel is then run and readings taken as required. At the conclusion of the run the zero and calibrate readings are repeated, again in still air.

9.8 Signal Overload Indication

Whenever a strain gauge amplifier signal overloads a digital panel meter, the numerical display automatically blanks, except for the sign and the most significant digit. In addition, a flag is available from the meter. By "ORing" the flag lines from each bank of six meters a flashing overload indicator is available to the operator, which readily distinguishes between the "not selected" strain gauge channels that are totally blanked except for the sign display.

Data acquired from an overloaded channel are automatically recorded as question marks.

10. STRAIN GAUGE AMPLIFIER MODULE

10.1 General

Three modules each contain six strain gauge amplifiers (San-E Instrument Co. Ltd, Type 6L4). All modules are identical except for the module assigned to measure the six components of force and moments from the strain gauged sting column. Included in this module is a small cathode ray oscilloscope (VU Data Corporation, Model PS910), switched to display the output waveform of any of the six amplifiers.

Another module is dedicted to measure strains from actuator hinge moments or *ad hoc* experiments incorporating strain gauges, while the third module is assigned to measure strains from pressure transducers within Scanivalves.

10.2 Strain Gauge Amplifier Performance

The strain gauge amplifiers provide an alternating current carrier voltage at a frequency of 5 kHz to strain gauge bridges. Each amplifier has eight switched sensitivities covering the range 20 to 5000 microstrains full scale. The amplifier output signal at full scale is 2 volts.

11. SCANIVALVE CONTROL MODULE

11.1 General

An important application of the Low Speed Wind Tunnel is to provide information for the visualisation of pressure profiles on aerodynamic surfaces of models. One solution which enables a multiplicity of pressure points to be measured almost simultaneously employs a multiplexing arrangement with one or more precision pressure transducers. Under these circumstances readings are taken fairly rapidly in sequence.

To enable a number of pressure lines to be switched to a common transducer, a range of pressure switches is commercially available. These switches are aptly named Scanivalves because they provide a means of sequentially monitoring up to 48 pressure points. Each input port is switched in turn to the diaphragm of a single strain gauge transducer by an electromechanical actuator. The model "D", commonly employed for wind tunnel pressure measurements at A.R.L., uses standard 12·7 mm (0·5 inch) diameter transducers which are easily interchangeable to cover different pressure ranges. Provision exists for up to six Scanivalves to be connected to separate channels of the Strain Gauge Amplifier Module (Section 10).

The method of stepping from port to port is similar to the way in which the well known telephone uniselector switch moves from one position to the next. Both have a solenoid and two pairs of contacts (each normally closed). One pair functions as an interrupter and the other provides an indication of the "HOME" condition.

Solid state controllers are commercially available which permit "MANUAL" operation or "AUTOMATIC" programmed switching of the Scanivalves. These controllers have been used successfully with the Pressure Measuring System installed in the A.R.L. Transonic Wind Tunnel.*

Similar principles have been used in the six Scanivalve drivers which form a section of the Scanivalve Control Module (SCM) (Fig. 13). Advantage has been taken of the flexibility of integrated circuits with TTL signal levels switching high current Darlington connected silicon transistors to simplify programming and to enable a compact design.

11.2 Settling Time

All mechanical switches take an appreciable time to make the physical transition from one state to the next. Electromechanical actuation of a switch is no exception; for example, the type of Scanivalves (D series) to be connected to the SCM takes an average of about 50 milliseconds to change from one port to the next port. Obviously during this transition period data derived from its transducer are in error.

To obtain acceptable accuracy, a further period of time is needed for the pressure changes to equalise in the cavity in which the transducer is mounted. An important factor which contributes to its duration is the magnitude of the pressure step functions encountered between one port and the next.

The sum of the above mentioned delays corresponds to a minimum period, referred to as "SETTLING TIME". Operated in the automatic mode the SCM allows preselection by a three decade thumbwheel switch of a common settling time for all channels in increments of 0·1 seconds from 0·1 seconds to 99·9 seconds. Until the preset settling time expires the pressure reading on the meter is either blanked or refers to the previous port reading.

11.3 Analogue to Digital Conversion

The six analogue signals derived from the Scanivalve transducers are multiplexed in the SCM and read in sequence by a single digital panel meter, the input being switched by six reed relays with normally open contacts. The bipolar meter has a three and a half digit capacity (i.e. maximum reading is 1999 digits) and provides both a visual display and analogue to digital conversion in BCD 1248 code with a maximum conversion time of 10 milliseconds.

11.4 Method of Scanning

Fast scanning rates are not mandatory for the Low Speed Wind Tunnel application but nevertheless, for a large number of pressures to be sensed, a reasonably rapid scan is desirable so that pressures remain sensibly stable during the monitoring period.

For a single Scanivalve, the maximum scanning rate is approximately the inverse of the sum of the delays that form the minimum settling time including the analogue to digital conversion time. Assuming no other limitations, it is possible to take readings at this rate.

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* A Pressure Measuring System for the A.R.L. Transonic Tunnel by Kittson G. R., and Willis J. B. Aero Note No. 333, Nov. 1971.

The SCM is currently preprogrammed to give a minimum settling time of 100 milliseconds which allows a maximum reading rate of about nine readings a second for a single Scanivalve.

For multiple Scanivalve operation a technique known as staggered cyclic scanning allows a considerable increase in the maximum rate at which measurements are possible. Suppose two Scanivalves are used and readings taken alternatively, then the required settling time is halved if stepping occurs immediately after a reading is taken. This approach has been adopted in the SCM which has provision for up to six Scanivalves to be scanned one after the other.

The six Scanivalve channels are identified by the alphabetical characters A through to F and each Scanivalve has 48 ports numbered 00 through to 47. Individual two digit thumbwheel switches allow selection of the number of ports to be used for each Scanivalve. If a given Scanivalve is not required then the dialling of any number greater than 47 introduces an automatic skip. This skip also occurs if that Scanivalve is not plugged in or when the selected number of ports has been measured. In the absence of skips the SCM reading sequence is A00, B00, C00, D00, E00, F00, A01, B01, and so on until the number of ports selected in each case are exhausted. When skipping occurs, the SCM automatically omits that reading and takes the next in the sequence. When all readings are taken an automatic "RESET" occurs and all Scanivalves are "HOMED".

The digital panel meter provides a convenient memory in which to store a reading until it is transferred to a peripheral. In addition, the meter provides a logic output pulse which lasts for the conversion period corresponding to the time it requires to take a reading. At the conclusion of this period the Scanivalve involved is stepped on, but the reading is stored and displayed until the longer of two periods has elapsed. These periods are either any additional time required for the next Scanivalve to settle or the time required for the reading to be stored in a peripheral. For example, a six character reading requires about 700 milliseconds to be printed by a Teletypwriter operating at 110 baud.

11.5 Measurement of Settling Time

Although the SCM is prewired for a minimum settling time of 0·1 seconds, and a selectable settling time which increments in steps of 0·1 seconds, it was thought prudent to include a capability to measure periods in the millisecond range. The basic arrangement is to load, at appropriate times, the three most significant decades of a five decade down counter with the three digits derived from the panel selector switch. The two least significant decades are prewired to a count of 99 corresponding to 99 milliseconds. When the counter is clocked at a frequency of 1 kHz, then a count of zero indicates completion of the dialled settling time. With staggered cyclic scanning a variation of the above approach in which the fundamental frequency of the clock is multiplied by the number of Scanivalves to be read allows a common selector switch and a single five decade counter-zero detector combination to give a measure of the fraction of the total settling time needed between one reading and the next.

A stable programmable oscillator is controlled by a decade counter connected to a BCD decoder with open circuit collectors. The number of active Scanivalves is sensed prior to each reading by the counter and the decoder switches capacitors such that the output frequency is either 1, 2, 3, 4, 5 or 6 kHz.

A Scanivalve is active provided:

(a) The Scanivalve is connected.

(b) The number of ports selected is less than 47.

(c) The port corresponding to the dialled number has not been reached.

11.6 Maximum Reading Rate

The SCM is fully compatible with the remainder of the DAS system which has a potential capacity to use fast reading rates. The Scanivalve system is relatively slow because of settling time requirements. Thus it is necessary to signal to the DSSM whether the SCM is "READY" or "NOT READY" by means of a flag.

One important precaution is that this "NOT READY" flag is not activated during the time that the DSSM is addressing a reading. In other words, this inhibit signal must occur before the DSSM commences to record a reading or alternatively after the reading is completed.

In the manual operating mode the SCM provides all needed controls to step the Scanivalves one port at a time and take visual readings from the digital panel meter. Settling time is inhibited in this mode and the readings are not recorded through the DSSM.

12. AUXILIARY MOTOR CONTROL MODULE

12.1 General

Whenever powered models are required in the wind tunnel a three phase rotary frequency changer is used to power one or two electric motors coupled to the propellers. The models are rigidly attached to pylons, strain gauged stings or coupled to the mechanical balance. The main purpose of installing motor driven propellers on the scale model is to simulate the air flow over an aerofoil in powered flight.

All controls necessary to start, stop and run the frequency changer are provided as illuminating press button switches on the panel of the Auxiliary Motor Control Module. The propeller speed is controllable between 3000 and 33,000 revolutions per minute. The lower frequency limit is set by the rotary frequency changer and the upper limit by the maximum rated rotational speed of the propeller motors.

Should the rotary speed of either propeller motor exceed a preselected value, power to the motors is automatically removed. Power can only be reapplied when the propeller speed falls below 6000 revolutions per minute (100 Hz). In addition, the temperature of the water cooled propeller motors is continuously monitored and power is automatically removed whenever a preset temperature is exceeded.

12.2 Tachometer

Each propeller motor contains a tachometer that produces two sinusoidal waveforms for each revolution of the motor shaft. An electronic counter counts the number of sinusoidal cycles that occur in a given gate time.

A gate time of 2·5 seconds was chosen which provides direct readings of propeller speed to 0·1 revolutions per second. The gate time is obtained by frequency dividing the 50 Hz mains supply. At the end of each 2·5 second gate period combinational logic gates provide a latch pulse to renew the display, followed by a counter reset pulse.

12.3 Overspeed Cutout

Switches located behind the front panel of the Auxiliary Control Module allow the operator to preset the maximum desired propeller speed. The switches set the reference states of a digital comparator while a decade counter chain provides the variable states for comparison. Should the comparator detect counter states equal to or greater than the set reference states, a relay is de-energised to switch-off power to the rotary frequency changer.

12.4 Recording of Propeller Speed

The Auxiliary Motor Control Module connects to two input channels of an Auxiliary Module (Section 8). The appropriate Auxiliary Data Selection switches, located on the front panel of the DSSM, enable either or both tachometer readings to be selected for recording.

The only other requirement for recording the data is to set the word length switches, located behind the front panel of the Auxiliary Module, to six.

13. EXTERNAL ADDRESSING OF DSSM

13.1 General

As no dedicated minicomputer exists in the Low Speed Wind Tunnel the DAS has, since installation in 1975, always acquired data through the internal address circuits of the DSSM (Section 3).

However, prior to installation, a preliminary evaluation study of external addressing of the DAS was implemented using an existing PDP-8/e with a sixteen bit expander unit.*

Although data addressing through the DSSM requires an eleven bit parallel word, the selection and supply of reference angles to the Model Control Deflections Module requires sixteen bit parallel words.

The flow diagram for the acquisition of data using external addressing is shown in Fig. 21.

13.2 Software Considerations

For operator simplicity a single general purpose program was written incorporating the code, formed in part by the state of the Data Selection Switches on the front panel of the DSSM, to automatically provide selective addressing for data gathering. Likewise, the program senses for a flag from the Read Switch before commencing a data gathering run. Hence, from the operators view point there is no apparent difference in the function or operation of front panel controls between the internal and external addressing modes.

13.3 Address Tables

Two address tables were compiled as partly shown in Figures 22*a* and 22*b*. One table listed the addresses required to obtain the code information (interrogation table) and the second table listed the addresses needed to gather the data. To standardise data processing, the address order of each table is compatible with that generated by the DSSM internal address circuits. To minimise the size of each table only the address of the first character in every code and data block is listed along with an increment number. The first line of each table therefore represents a twelve bit address and the following line a twelve bit increment number. This sequence is repeated two lines for each block until all blocks are defined.

In operation, the program reads the first line and outputs the address word umodified. The character at this address is read, stored and packed. The increment number is then read, stored and checked for zero value. If the stored increment number is not zero then the least significant bits of both the address word and the stored increment word are advanced one bit and the next character read, stored and packed. This process is repeated until eventually the stored increment number becomes zero, signifying that the last character of the block has been reached. The program then advances to accept the next address line.

At the commencement of each run all listed interrogation addresses are transmitted to the DAS and the code replies stored. The states of the code characters so obtained actuate program skips during reading of the data address table. Each skip so generated advances the program by two lines in the data address table to exclude the unwanted data block.

13.4 Model Control Deflections

In addition to providing the data address to obtain angular data, provision exists for the servo reference angle to be inserted by computer instead of by the manually set thumbwheel switches. To individually control a sign and a three digit decimal reference angle to any one of the three servo systems requires fifteen bits with an additional bit to latch the reference.

14. DATA HANDLING

14.1 General

In the internal addressing mode, data gathered by the DAS are available as 8 bit serial or parallel ASCII. Initially, the serialised data were transmitted at 110 baud through a conventional 20 milliamp current loop to a standard ASR33 Teletypewriter fitted with a paper punch.

Later, it became possible to store data directly on disks of the central computer. Verification of the character string is provided by an echo to the DAS terminal.

With the changeover from current loop to RS 232, the DAS terminal was replaced by a Teletypewriter model 43 and operation increased to 300 baud.

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* A Digital Input-Output Multiplexer, A.R.L. Aero. Tech. Memo. No. 297, March 1976 by Farrell A. J., Ferrarotto P., Harvey J. F., and Sutton C. W.

The next step is to incorporate a cassette recorder containing semiconductor memory to:

(1) Store raw data from the DAS off-line from the main computer.

(2) Record processed data from the main computer for off-line viewing on the graphics display unit (Section 15).

(3) Enable multiplots to be made off-line on a digital plotter.

The DAS, cassette recorder, digital plotter, graphics display unit, keyboard and printer terminal and the main computer are intended to be readily interconnected in a varity of combinations by a switching unit.

14.2 On-line Considerations

Although facilities were incorporated into the DAS for possible future use with a dedicated minicomputer, capital and running costs of a stand-alone dedicated processor and the following factors detracted from this approach.

(1) Existing data reduction programs were in FORTRAN IV (DEC) for running on the DECsystem-10.

(2) Aerodynamicists were familiar with programming in FORTRAN on the main computer and were reluctant to change. To provide similar facilities with a minicomputer would be an unnecessary duplication.

(3) The main computer has special maintenance and staffing arrangements which would be difficult to match with a dedicated system.

(4) The peripherals and capacity of the main computer were adequate for coping with the tunnel data requirements but would be expensive to provide in a dedicated system.

With the DAS conected to the main computer the following difficulties exist.

(1) The uncertainty of the computer being available whenever required by tunnel staff.

(2) The need to operate within the constraints of a time sharing mode.

(3) The rate at which data can be transmitted for storage.

These disadvantages are expected to be minimised by provision of temporary data storage within the tunnel control room as outlined in Section 14.1.

In practice the down time of the central computer is very low (less than 2%) however, a succession of short duration "crashes" is a more practical problem to tunnel staff than a notified longer (hours) downtime. Thus tunnel operation under interrupted on-line conditions could continue off-line provided processed data were not immediately required.

Operation in the time sharing mode has been found acceptable with the internal address circuits of the DAS arranged to respond to X-ON, X-OFF calls from the computer The program which runs on the DECsystem-10 to accept characters from the DAS for storage on disk and subsequent echo to the DAS terminal, also transmits X-ON calls at 5 second intervals whenever the buffer is not full and no characters have been received from the DAS during the previous 5 seconds. This avoids the possibility of a false "buffer full" call which would otherwise initiate indefinite HOLD on the DAS address circuits.

On the few occasions when unacceptable time sharing delays occur it will be possible to maintain tunnel operation by off-line storage of raw data on a digital cassette unit.

At present the data rate is set by the speed of the DAS terminal because all data are considered static. However, should the need arise to acquire dynamic data then the maximum on-line and off-line storage speed is 9600 baud with the arrangement described in Section 14.1.

14.3 Real Time Display

With on-line storage of acquired data it is possible for the data reduction programs to select specific processed data for return to the DAS terminal.

Rather than produce print outs of processed results as they become available, a quick look graphics system is considered more appropriate. At the end of a tunnel run tabulated results are available from a line printer peripheral of the main computer.

The quick look graphics system* uses a Tektronix storage display monitor unit controlled by a National Semiconductor Corp. PACE microprocessor.

All characters transmitted by the main computer to the DAS terminal are also received by the graphics system. However, only special control characters and character combinations are recognised and used by the graphics system; unrecognised characters are automatically ignored.

The graphics system enables up to 8 channels of processed data to be displayed on scaled coordinates either simultaneously with each channel being allocated a portion of the screen, or in a cyclic sequence with each channel using the full screen area.

15. CONTROL CONSOLE

15.1 General

The control console, designed at A.R.L. and constructed commercially, contains twenty two module bays each fitted with telescopic runners (Im-Slides) to provide fast and easy access to circuits contained within the modules. The modules can be slid from the console, rotated and locked in position.

The console (Fig. 23) has a row of single height modules along the front section and double height modules along both side sections. The single height modules enable tunnel operators to view the aerodynamic model through windows in the control room and the working section of the tunnel.

15.2 Forced Air Cooling

The control console contains air ducts and an air blower to distribute filtered forced air through selected modules. This minimises hot spots and the slight pressuration reduces dust entry into the console.

15.3 Mains Protection

The DAS is entirely powered with 240 volt 50 Hz mains supplied through a core balanced relay for protection of personnel servicing the DAS.

For safety and convenience, a single mains shut down switch is located at a prominent position on the control console.

16. SYSTEM EVALUATION

In addition to laboratory evaluation checks it was possible for some modules to be assessed under actual wind tunnel operating conditions before the system was completed. This illustrates the versatility of the system design as most modules are self-contained and able to perform useful functions without necessarily being interconnected to form the DAS.

The design approach is probably best understood if the DSSM is considered the data gatherer and the other modules sense parameters to provide data in the correct form for the DSSM. Hence, for example, the Model Control Deflections Module, when used separately, controlled and displayed directly in degrees the actual angles of port and starboard flaps of a Torana and an Ikara model mounted in the wind tunnel.

Likewise, the Auxiliary Motor Control Module when used separately displayed the propeller speed of a powered Victor CT4 model and acted as a safety overspeed monitor.

Prior to the completion of the Scanivalve Module, the DSSM with a Strain Gauge Amplifier Module and a Strain Gauge Control Module were used to gather and record air pressure profiles in the nose section of a Nomad model.

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* A Microprocessor Controlled Graphics Display System by Sutton C. W., Harvey J. F. and Cleave G. A., A.R.L. Note No. 396.

In all cases, tunnel time and operator monotony were reduced and operator acceptance of the modules was gratifying. The only serious difficulty encountered was the intermittancy of several commercially obtained digital panel meters caused by poor alignment of internal connector pins.

Following installation of the DAS the system was extensively used on a Royal Thai Air Force model.

On-line operation and graphics display facilities have been added to increase the versatility of the installation and further extensions involving microprocessor based signal conditioners and controllers are envisaged.

APPENDIX 1

Specification of Data Sources Forming the DAS

The DSSM input digital code is positive logic, BCD 1248 code with TTL compatible logic levels ("1" state +2·4 to +5·0 volts and "0" state 0 to +0·8 volts). The DSSM output digital code is positive logic, ASCII code. The eight bit parallel output having TTL compatible logic levels while the serial output meets EIA Standard No. RS-232C. Each data source is tabled below listing the range and units.

FIXED DATA

Data	Range	Units
Time	0000 to 2400	Hours and Minutes
Day	001 to 365	Days
* Relative Humidity	20 to 100	Percentage
* Air Temperature	00·0 to 99·9	Degrees Celsius
* Atmospheric Pressure	890 to 1060	Millibars
Tunnel Kinetic Pressure	0000·0 to 7999·5	Pascals

* Data Inputs are provided for future inclusion of these data.

PRESET DATA

Data	Range	Units
Code	00 to 99	Not assigned
Configuration	00 to 99	
PD1	±99·99	
PD2	±99·99	
PD3	±99·99	
PD4	±99·99	
PD5	±99·99	
PD6	±999·99	
PD7	±999·99	

MODEL CONTROL DEFLECTION

Data	Range	Units
CS1	±99·9	Degrees
CS2	±99·9	Degrees
CS3	±99·9	Degrees

MODEL ATTITUDES

Data	Range	Units
Angle of Attack (Alpha)	000·00 to ±179·99	Degrees
Angle of Side Slip (Beta)	000·00 to ±179·99	Degrees
Angle of Pitch (Theta)	000·00 to ±179·99	Degrees
Angle of Roll (Phi)	000·00 to ±179·99	Degrees

MECHANICAL BALANCE

Data	** Range	Units
Lift	5280·00 in 0·05 steps	Newtons
Drag	1760·00 in 0·05 steps	Newtons
Cross Stream	1760·00 in 0·05 steps	Newtons
Roll Moment	1056·00 in 0·01 steps	Newton metres
Pitch Moment	1056·00 in 0·01 steps	Newton metres
Yaw Moment	1056·00 in 0·01 steps	Newton metres

** The load facility (Section 7·1) provides each data channel with an off-set between ±9999·99.

STRAIN GAUGE AMPLIFIERS AND CONTROL

Data	Range	Units
12 Channels (All identical)	±1999	Calibrated in micro strains
Amplifier Sensitivity	1	20 micro strains full scale
Amplifier Sensitivity	2	50 micro strains full scale
Amplifier Sensitivity	3	100 micro strains full scale
Amplifier Sensitivity	4	200 micro strains full scale
Amplifier Sensitivity	5	500 micro strains full scale
Amplifier Sensitivity	6	1000 micro strains full scale
Amplifier Sensitivity	7	2000 micro strains full scale
Amplifier Sensitivity	8	5000 micro strains full scale

AUXILIARY

Data	Range	Units
16 Channels (All identical)	From 1 to 8 Characters	Assigned by Operator

SCANIVALVE

Data	Range	Units
6 Channels each with 48 pressure port capability	±1999	Relative with respect to a reference pressure
Channel Identification	A to F	
Port Identification	00 to 47	

AUXILIARY MOTOR CONTROL

Data	Range	Units
Propeller (2 Channels)	000·0 to 999·9	Revolutions per Second (Hz)

TUNNEL CONTROL 1

Data	Range	Units
Kinetic Pressure (Reference Pressure)	0000·0 to 7999·5	Pascals
Kinetic Pressure	0000·0 to 7999·5	Pascals

(Tunnel display slave from Fixed Data Module)

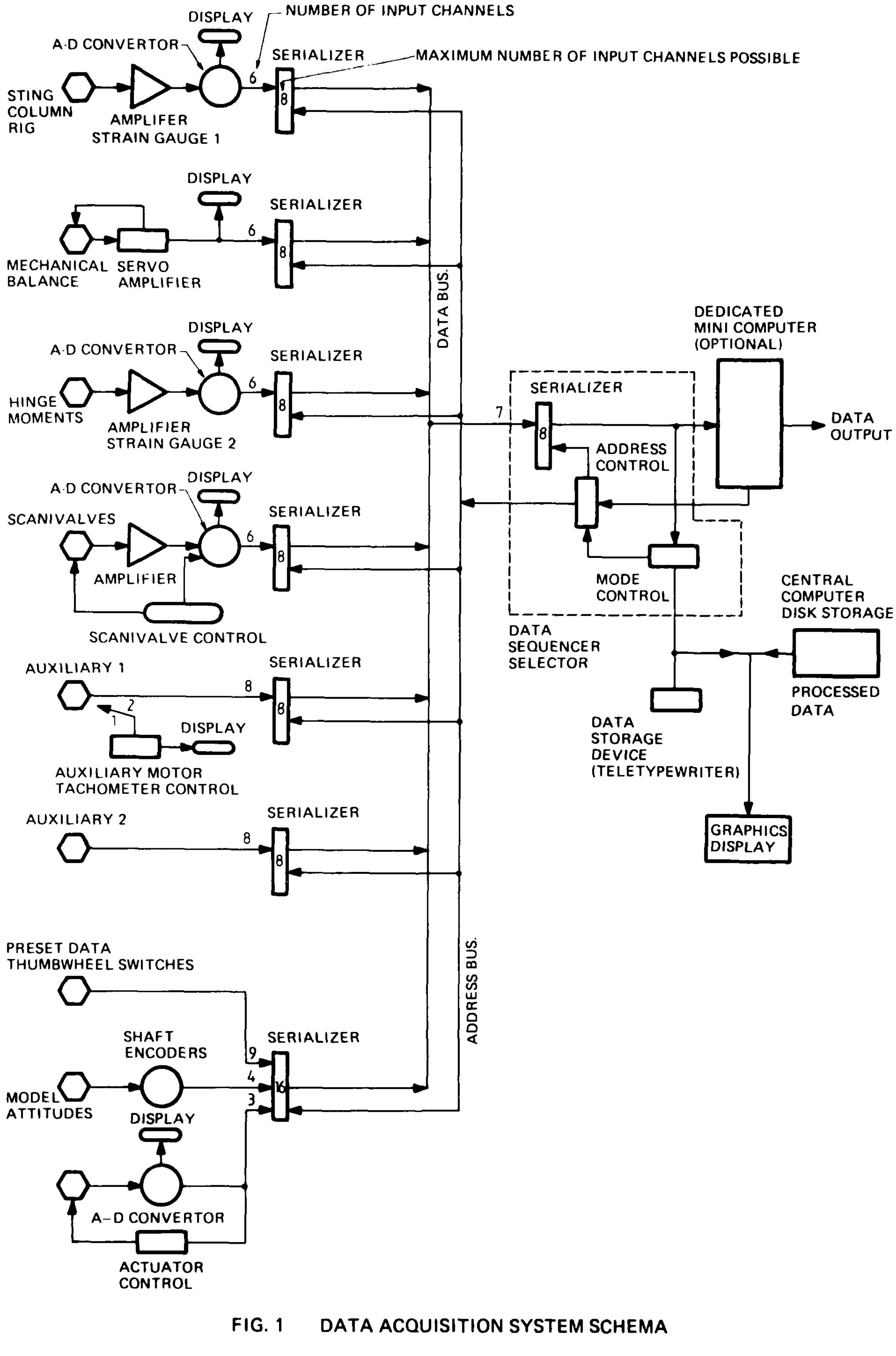

FIG. 1 DATA ACQUISITION SYSTEM SCHEMA

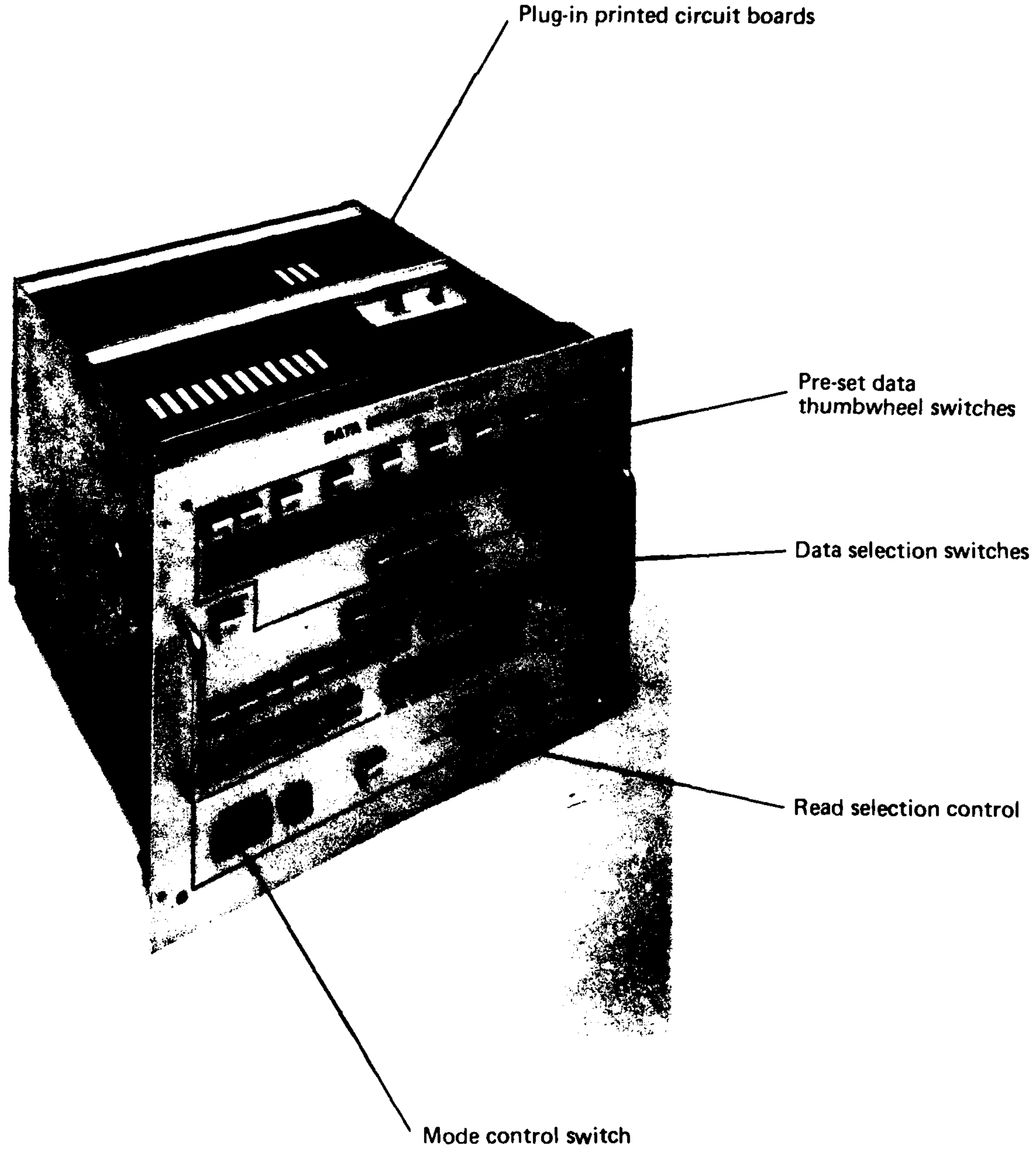

FIG. 2 DATA SEQUENCER SELECTOR MODULE (DSSM)

0935 072 32 27·6 0981 3257·5 Fixed Data Block
111101001 0101 000 111000 11000000 00000000
565000 000000 A08 B07 C00 D00 E99 F10

12 34 +16·00 −26·11 +12·34 +223·21
+177·3 −054·32

+1280·05 +0760·35 −0127·00

227·5 227·5

+0876 +0775 +1022

A+1123 B+0876 C+0164 D+0014 F+1118 A+1139 B+0911 F+1123
A+1142 B+0936 F+1137 A+1157 B+1005 F+1158 A+1175 B+1015
F+1179 A+1198 B+1078 F+1188 A+1215 B+1125 F+1216 A+1278
B+1177 F+1233 A+1304 F+1244 F+1256 F+1262

Figure 3A Typeout Containing Fixed Data Block

12 34 +16·00 −26·11 +12·34 +223·21
+177·3 −045·32

+1280·05 +0760·35 −0127·00

227·5 227·5

+0876 +0775 +1022

A+1123 B+0876 C+0164 D+0014 F+1118 A+1139 B+0911 F+1123
A+1142 B+0936 F+1137 A+1157 B+1005 F+1158 A+1175 B+1015
F+1179 A+1198 B+1078 F+1188 A+1215 B+1125 F+1216 A+1278
B+1177 F+1233 A+1304 F+1244 F+1256 F+1262

Figure 3B Typeout Without Fixed Data Block

0000 000 00 0000 0000 000000
111101001 0101 000 000001 00000010 00000001
334370 006400 @00 @00 @00 @00 @00 @00 Scanivalves not connected
12 34 +16·00 −26·11 +12·34 +223·21
?????? ?????? Data fault Model Attitude

???????? Data fault Mechanical Balance

−35·64

???????? Data fault Auxiliary 2

−0008 −0060 +0010 −0007 ????? Data fault Strain Gauge Channel E

+1953 −1257

Figure 4 Typeout With Diagnostics

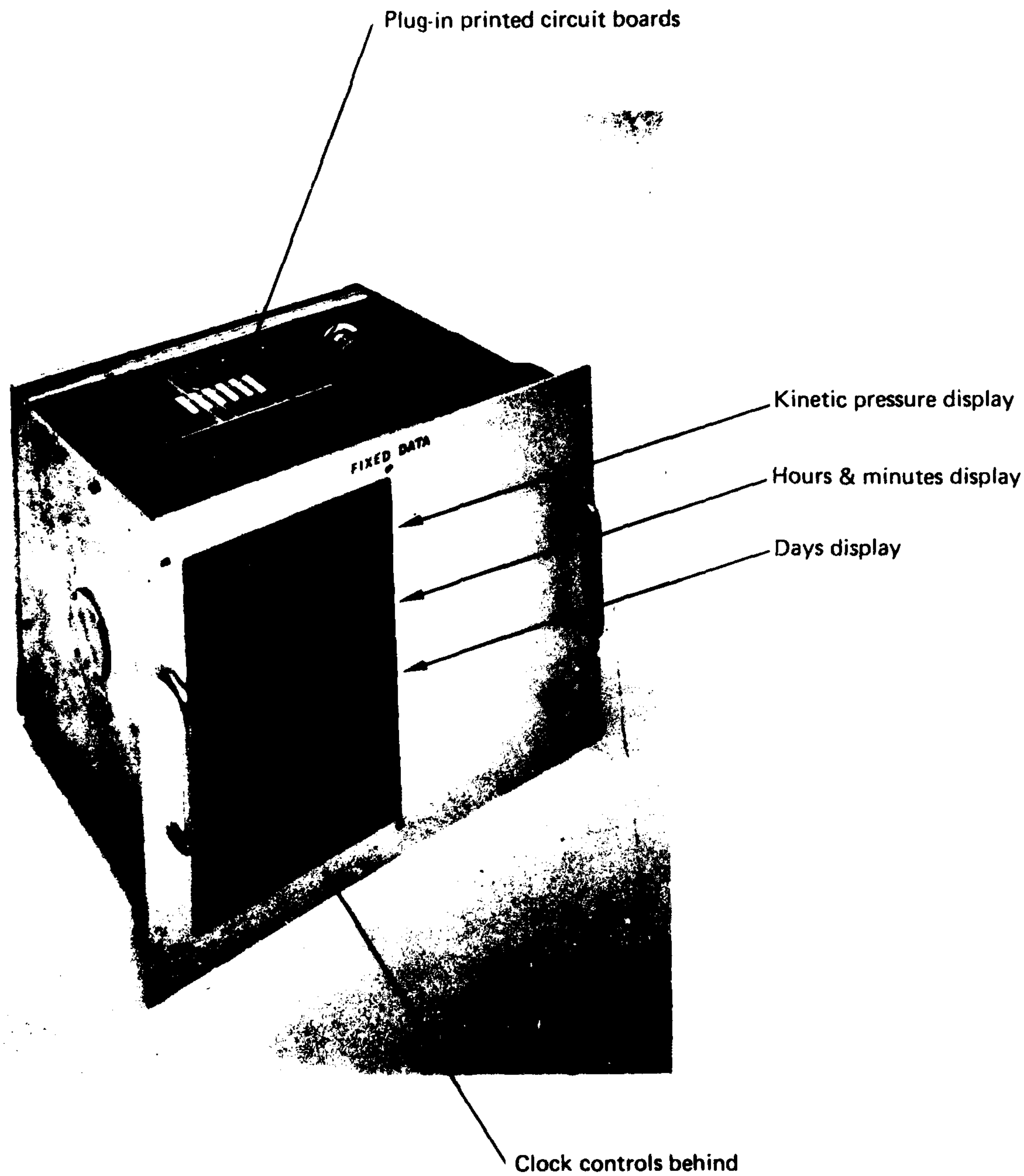

FIG. 5 FIXED DATA MODULE

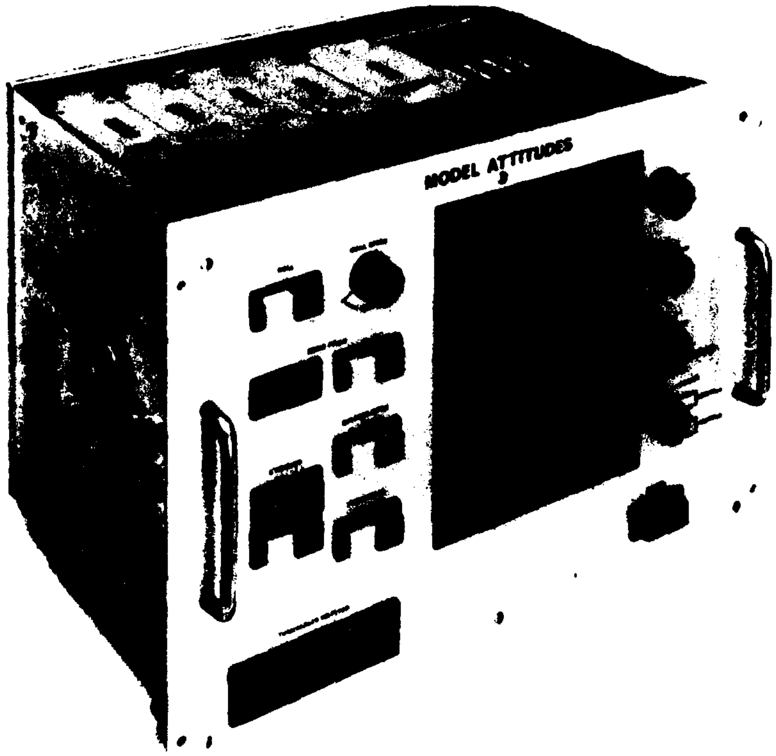

FIG. 6 MODEL ATTITUDES MODULE

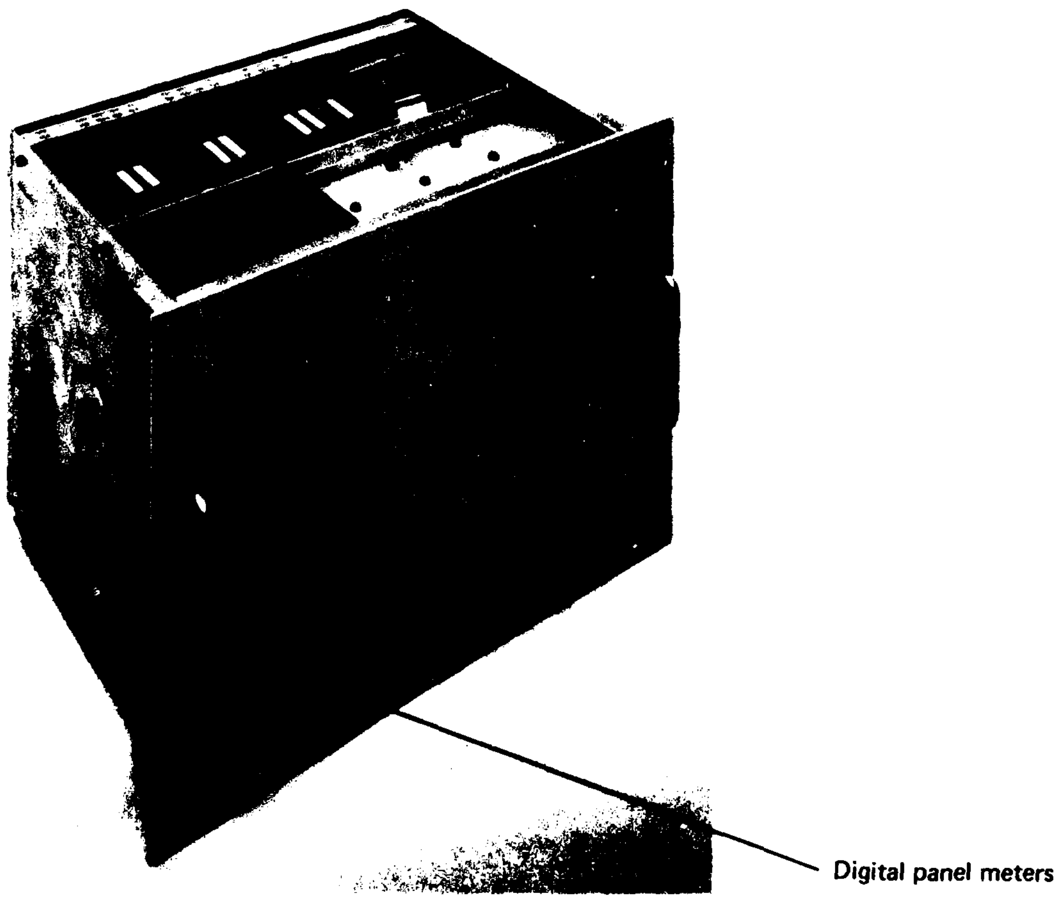

FIG. 7 MODEL CONTROL DEFLECTIONS MODULE

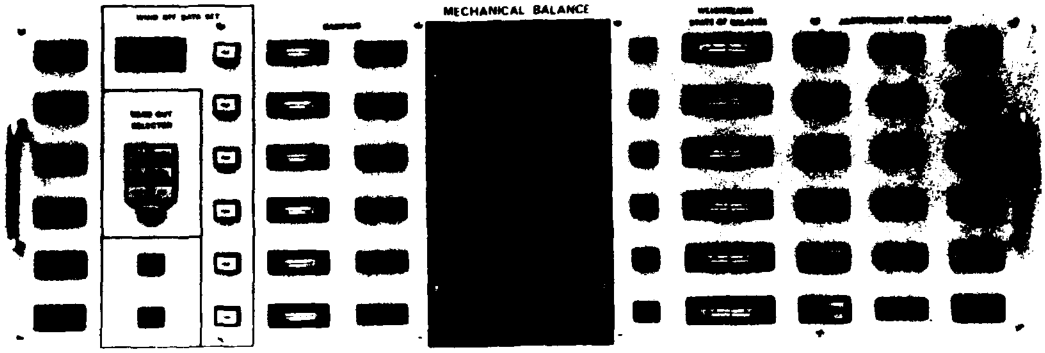

FIG. 8 MECHANICAL BALANCE MODULE

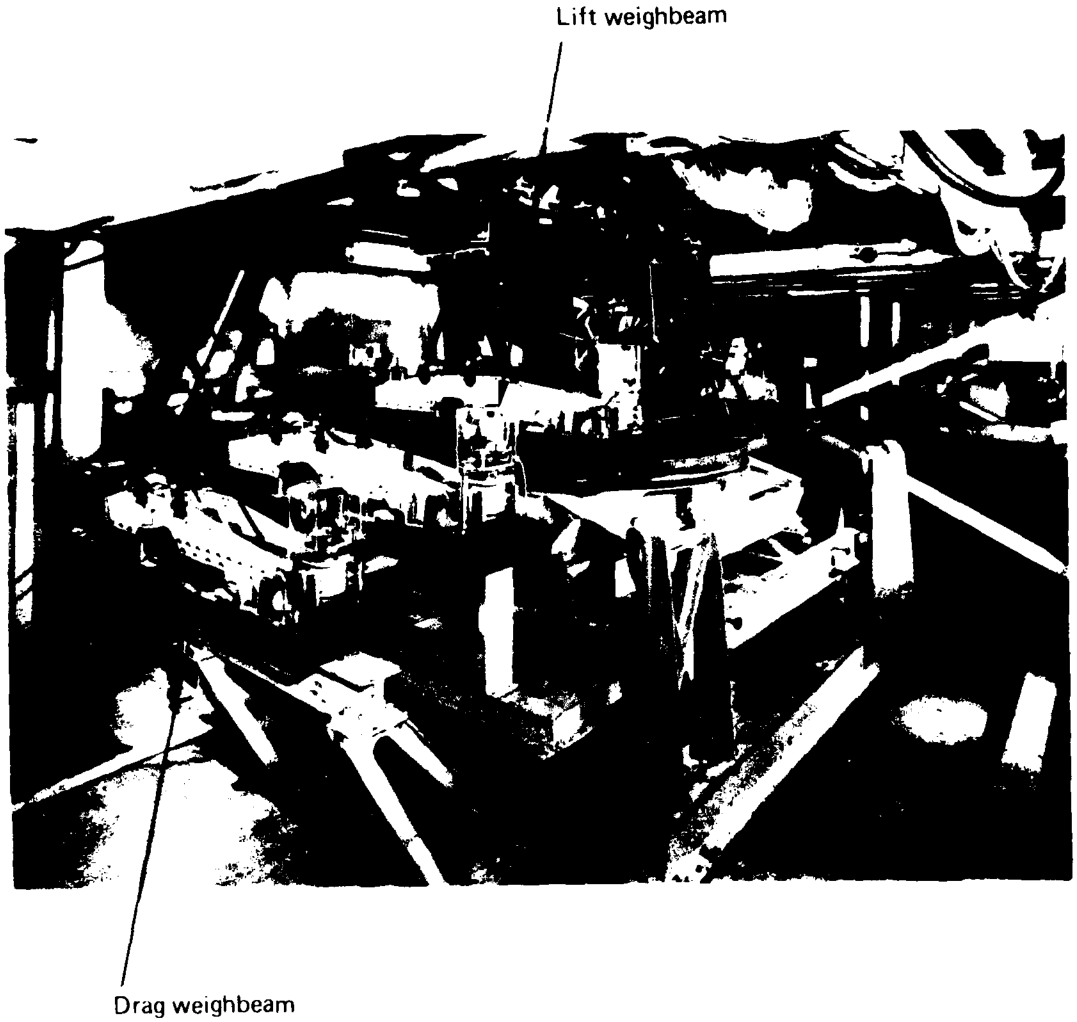

FIG. 9 AUTOMATIC SIX COMPONENT MECHANICAL BALANCE

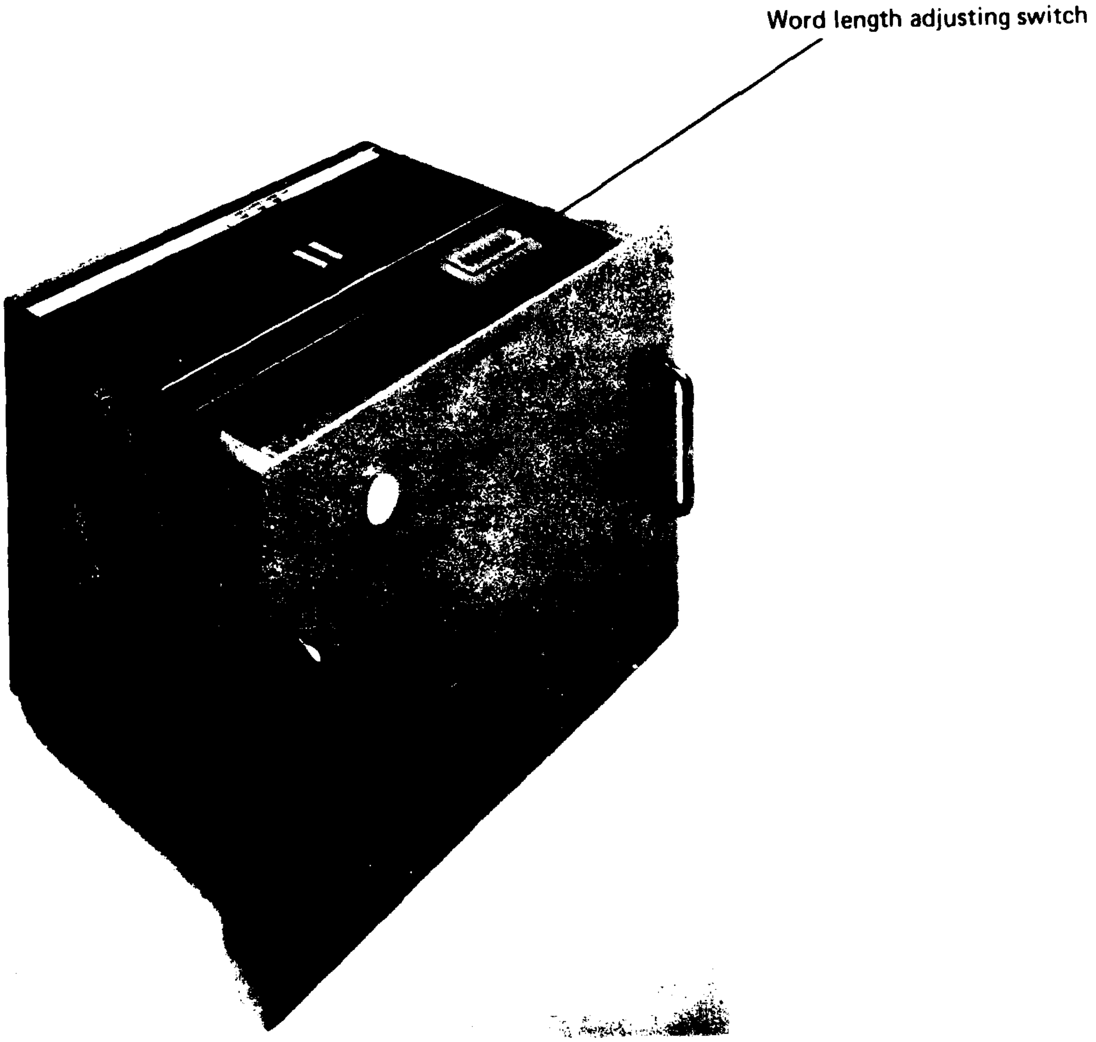

FIG. 10 AUXILIARY MODULE

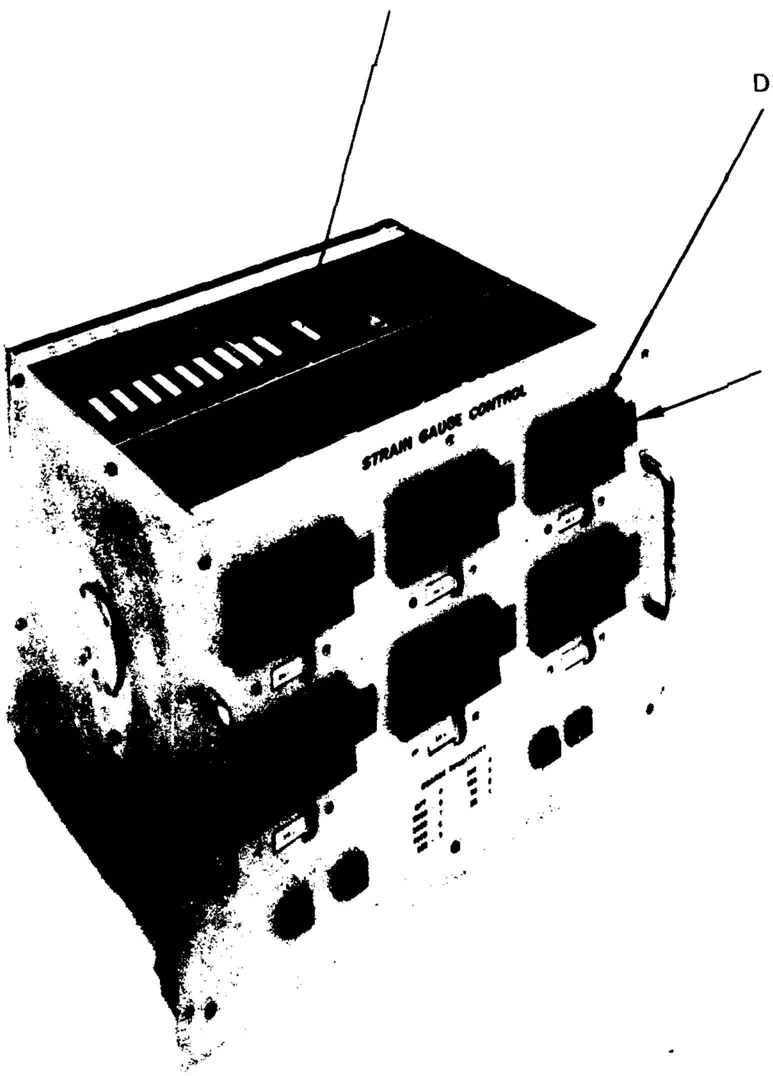

FIG. 11 STRAIN GAUGE CONTROL MODULE

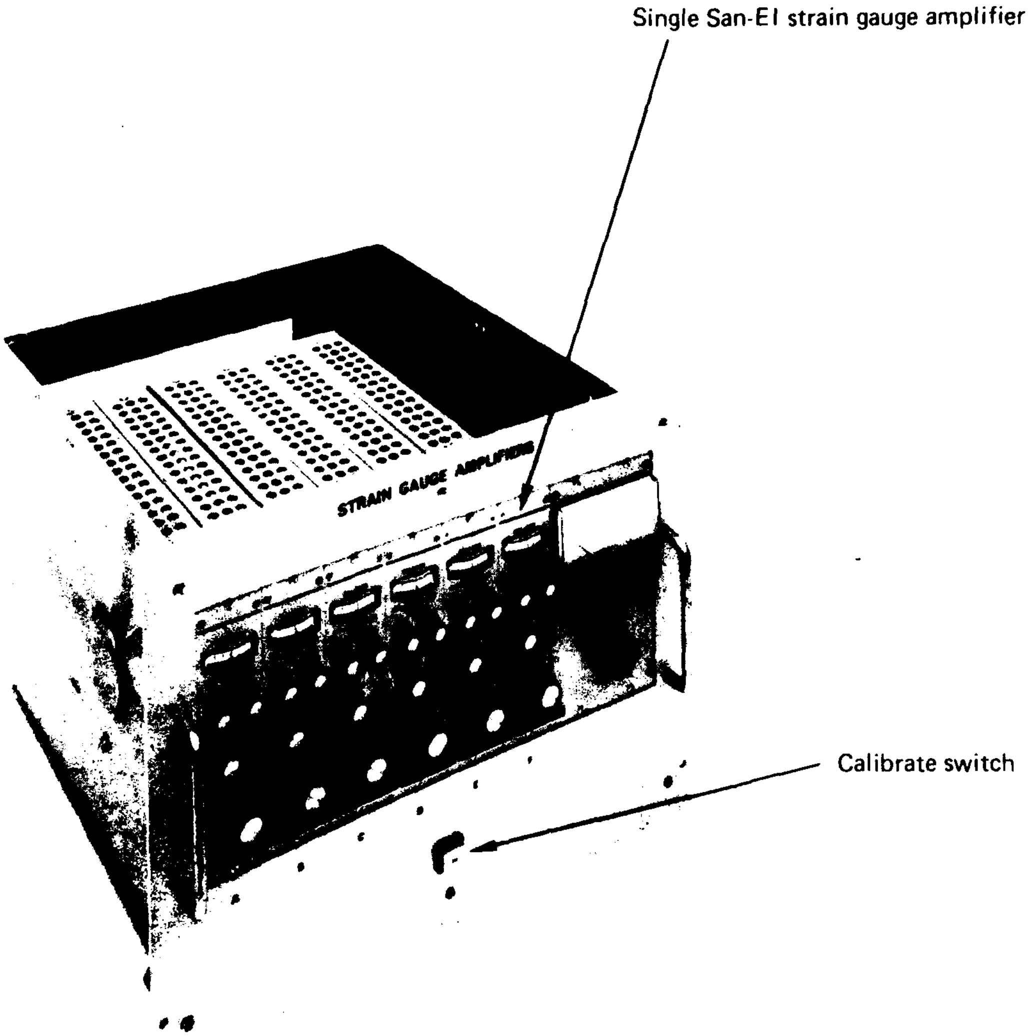

FIG. 12 STRAIN GAUGE AMPLIFIER MODULE

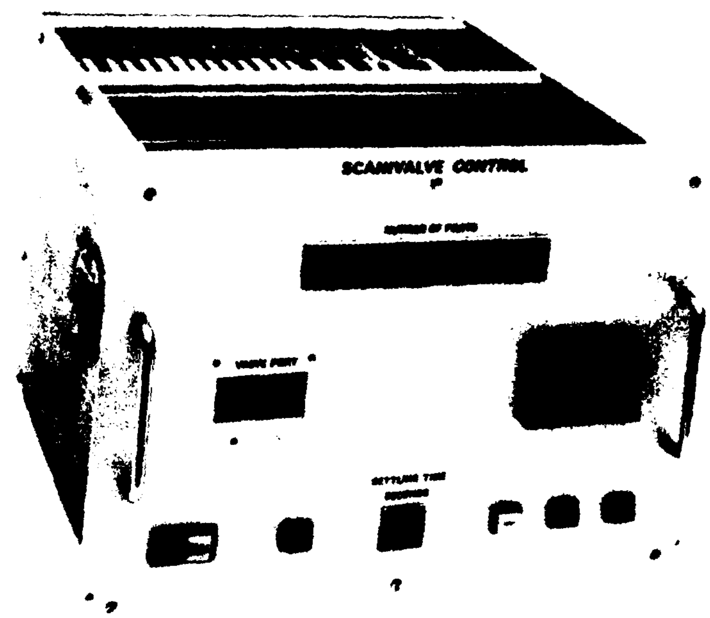

FIG. 13 SCANIVALVE CONTROL MODULE

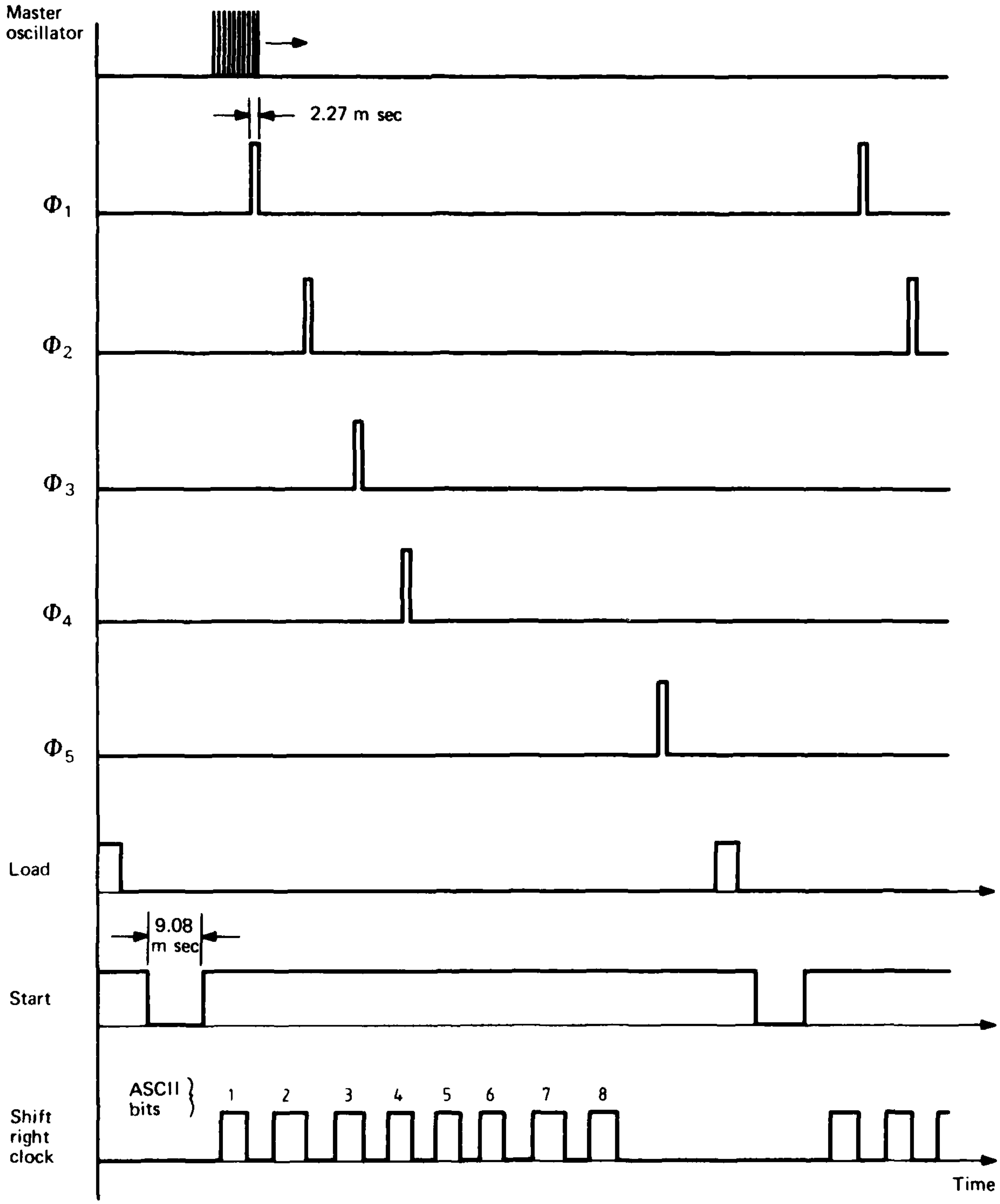

FIG. 14 PULSE LINES DERIVED FROM THE MASTER OSCILLATOR WHEN OPERATED IN TTY MODE

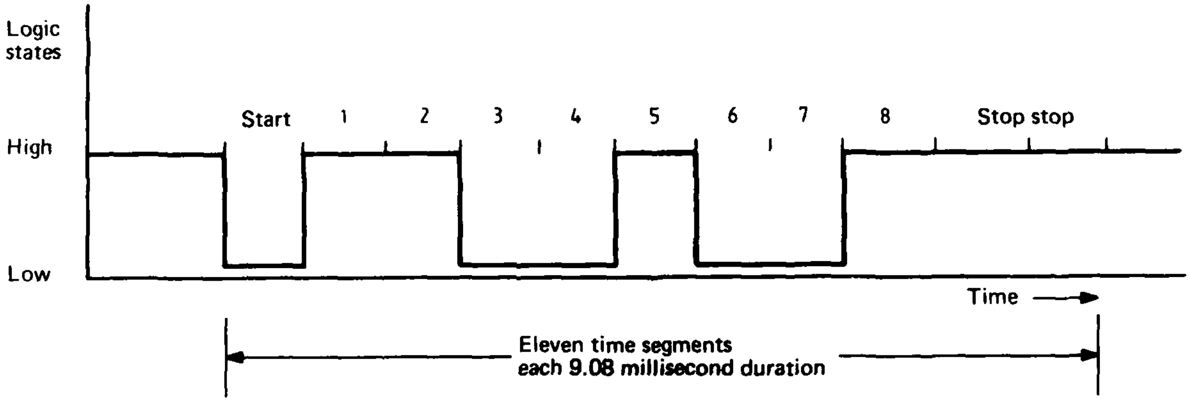

FIG. 15 SERIALIZED WAVEFORM, CORRESPONDING TO NUMERAL '3' GENERATED TO CONTROL SIGNAL CURRENT TO TELETYPEWRITER

0935 072 32 27·6 0981 32·57	Fixed Data
111101001 0101 110 111000 11111111 11111111	Data Selection Sw Code
565000 376340 A08 B07 C99 D99 E00 F10	Strain Gauge Amp. Sen. then Scanivalve Port No.
12 24 +16·00 −26·11 +12·34 +223·21 +177·3 −045·332 +12·1 +15·1	Preset Data
+1280·05 +0760·35 −017·00	Mechanical Balance
+123·456 +123·45 +123·4 +1234 +123 +12 +1 +123·455	Auxiliary 1
−123·456 −123 −12 12 12 12 −12 +12	Auxiliary 2
+0856 +1278 +1009	Strain Gauge 1
−0004 −0014 −0478 −1683 +1978	Strain Gauge 2
A+1123 B+0876 E+0026 F+1118 A+1139 B+0911 F+1123 A+1142 B+0936 F+1137 A+1157 B+1005 F+1158 A+1175 B+1015 F+1179 A+1198 B+1078 F+1188 A+1215 B+1125 F+1216 A+1278 B+1117 F+1233 A+1304 F+1256 F+1262	Scanivalve

Figure 16 Typeout Showing Data Blocking

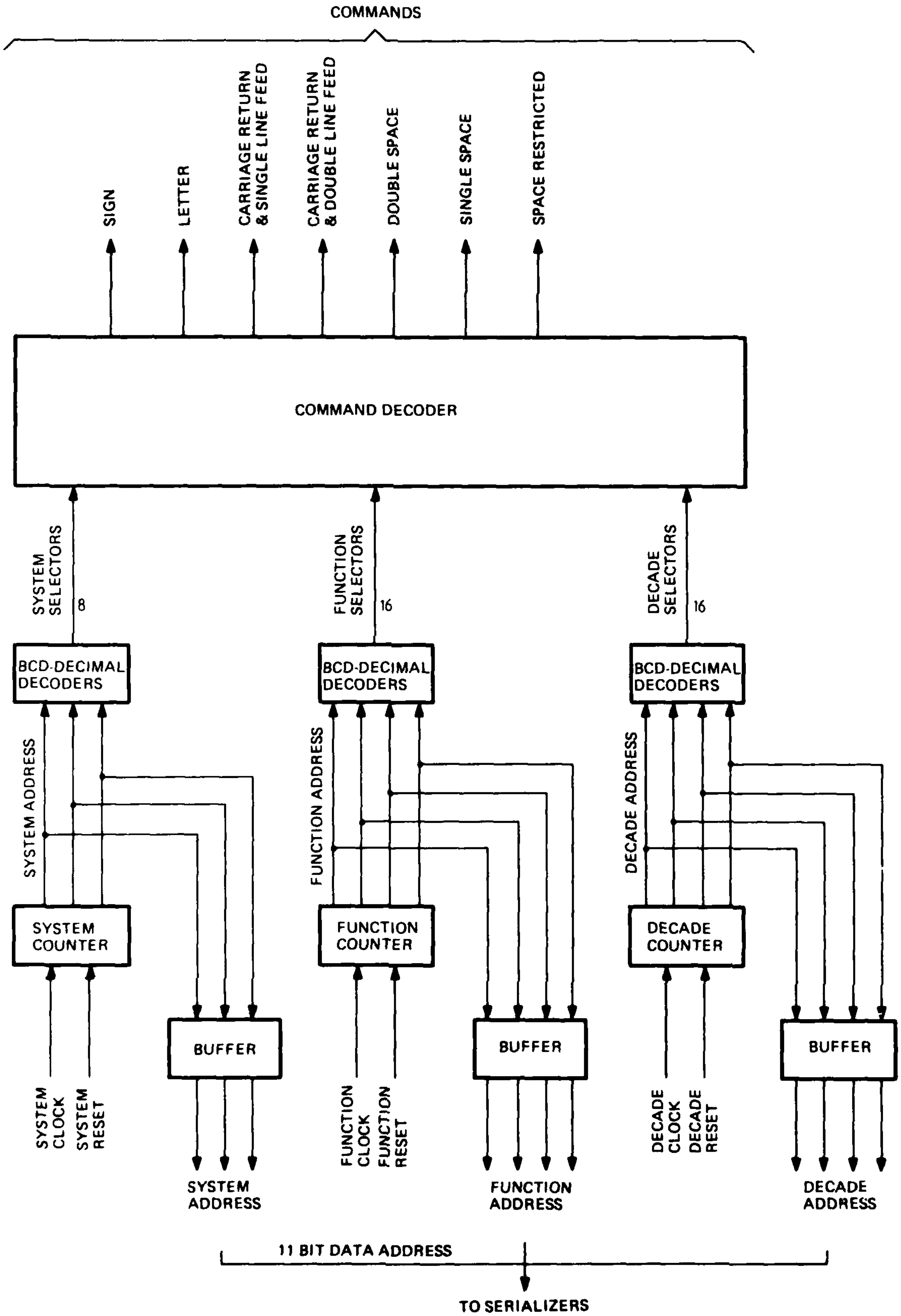

FIG. 17 DATA ADDRESS & COMMAND GENERATION

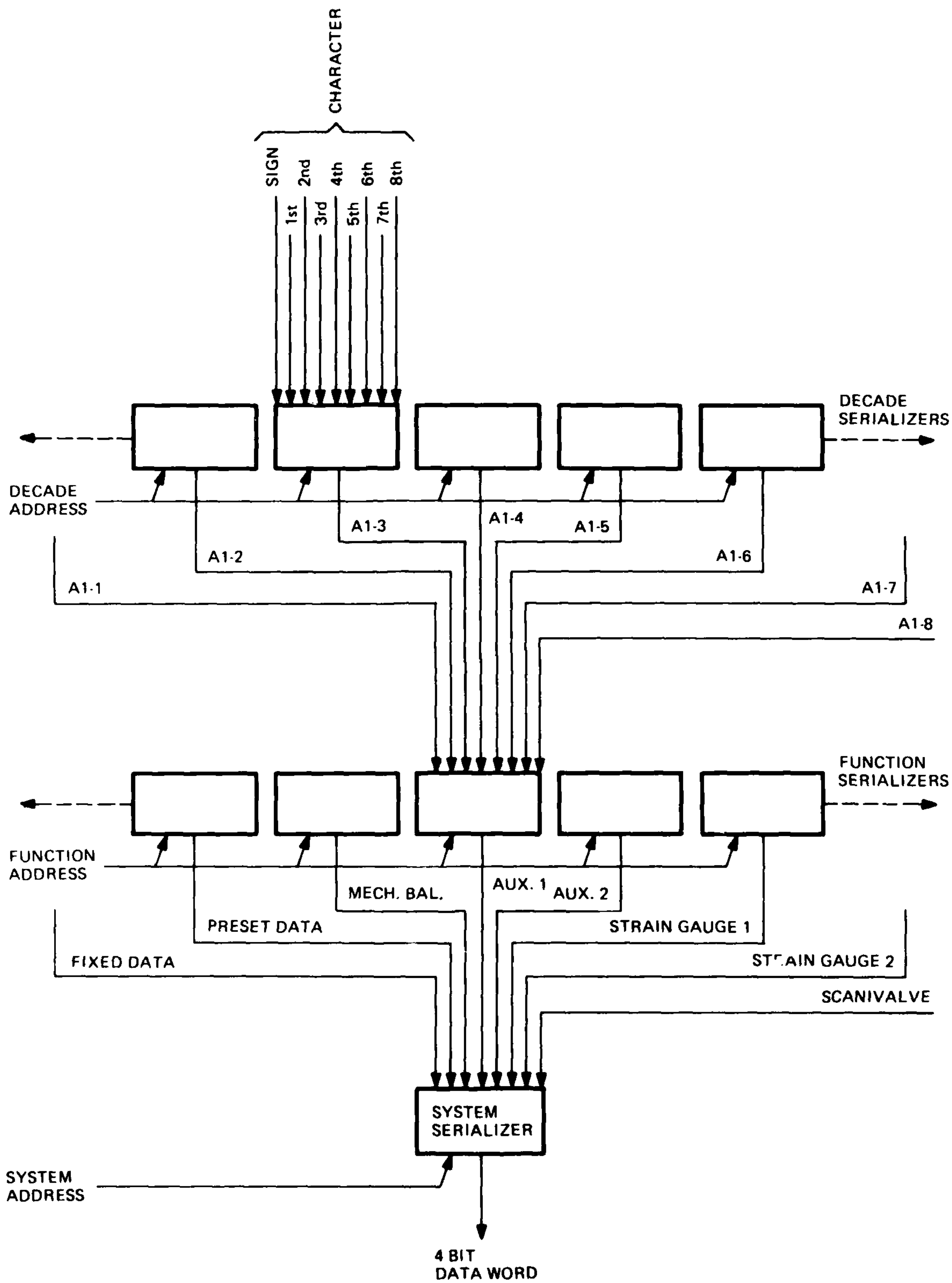

FIG. 18 DATA GATHERING BY SERIALIZERS

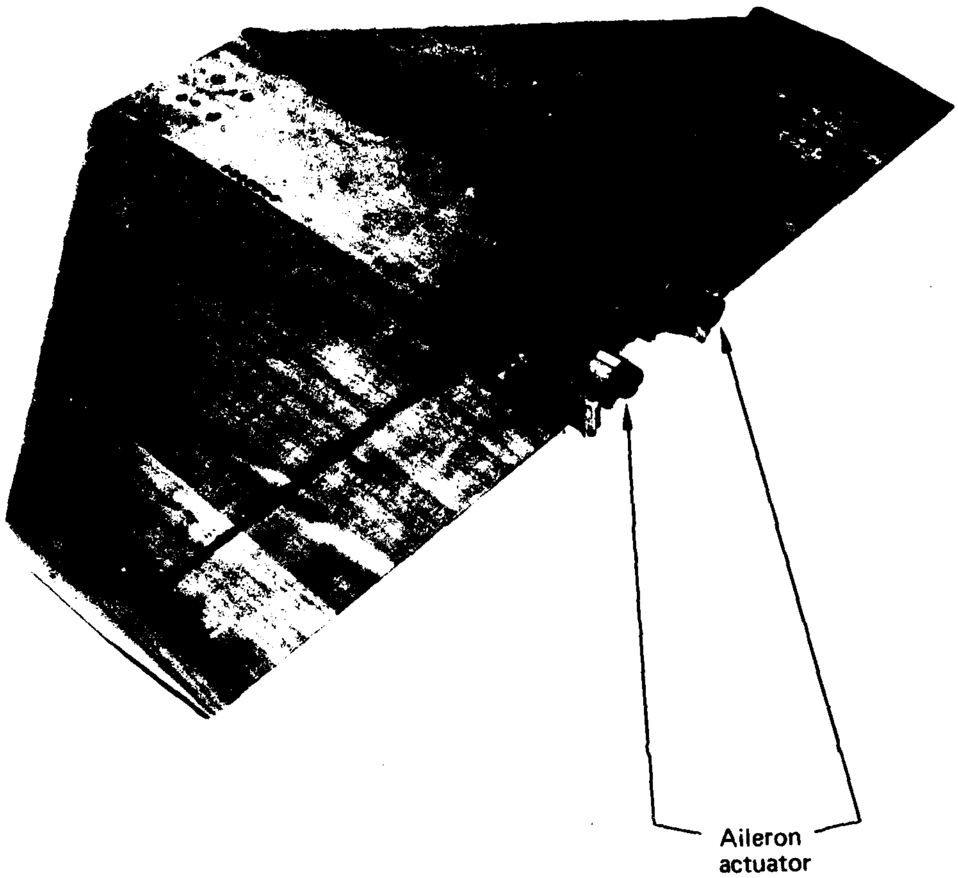

FIG. 19 ACTUATORS FITTED TO THE AILERONS OF AN IKARA MODEL WING

0935 072 32 27·6 0981 3257·5
000000000 0000 000 000000 11111111 11111111

+123·456 +123·45 +123·4 +1234 +123 +12 +1 +123·456	Auxiliary 1
123·456 −123 −12 12 12 12 −12 +12	Auxiliary 2

Note additional space in lieu of sign

Figure 20 Typeout Showing Variable Word Length in Auxiliary Channels

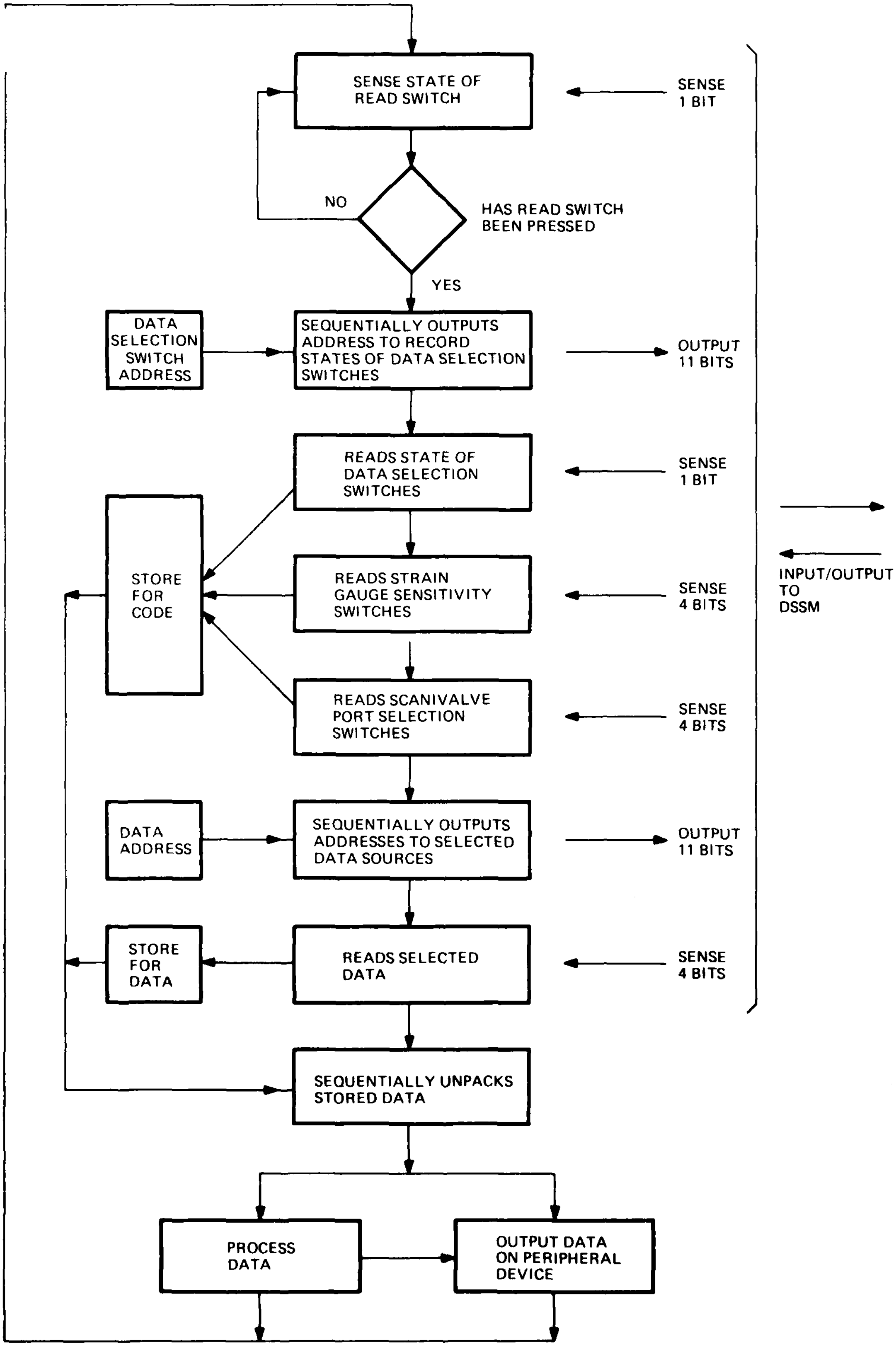

FIG. 21 FLOW CHART – COMPUTER PROGRAM TO CONTROL DSSM

Line No.	Octal Address	Date Selection Switch
1	0007	Fixed Data
2	0100	Code
3	0102	Configuration
4	0103	Preset Data 1
40	0200	Strain Gauge 1-A
41	0201	Strain Gauge 1-B
67	0360	F Scanivalve
68	0361	10^1
69	0362	10^0

Figure 22A Table of Interrogation Addresses

Line No.	Octal Starting Address	Data Source
1	0000	Time and Day
2	7771	
3	0020	Humidity and Temp.
4	7772	
5	0040	Barometric Pressure
6	7774	
43	2400	Strain Gauge 1-A
44	7773	
55	3400	Scanivalve
56	7771	

Figure 22B Table of Data Starting Address and Data Increments

FIG. 23 COMPLETED CONSOLE INSTALLED IN THE CONTROL ROOM OF THE LOW SPEED WIND TUNNEL

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